International Journal of Advanced Engineering Research and Science

(IJAERS)

An Open Access Peer-Reviewed International Journal

International Journal of Advanced Engineering Research and Science (IJAERS)

Vol-10, Issue-12

December, 2023

Editor in Chief

Dr. Swapnesh Taterh

Chief Executive Editor

S. Suman Rajest

Vol-10, Issue-12, December 2023

(10.22161/ijaers.1012)

Study on Control of Inverted Pendulum System Based on Simulink Simulation

Yongsheng Li, Jiahui Feng, Ruei-Yuan Wang, Ho-Sheng Chen, Yongzhen Gong*

School of Mechanical and Electrical Engineering, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China

*Corresponding author

Abstract— *This study aims to conduct control research on an inverted pendulum system using the Simulink simulation platform. The inverted pendulum system is a classic nonlinear dynamic system with important theoretical and practical applications. Firstly, establish a mathematical model of the inverted pendulum system, including the dynamic equation of the pendulum rod and the sensor measurement model. Subsequently, the PID (proportional integral differential) controller design method based on the inverted pendulum system and the fuzzy PID controller design methods were verified through simulation experiments. The ultimate goal is for the designed fuzzy PID controller to effectively stabilize the inverted pendulum system in the vertical position and achieve fast tracking of the target position. Simulation and experimental results show that compared to traditional PID controllers, fuzzy PID controllers can quickly stabilize the pendulum in the target position and have good practicality, stability, speed, and accuracy. Future research can further explore the application of other advanced control strategies in inverted pendulum systems, as well as their potential applications in practical engineering.*

I. INTRODUCTION

The initial research on inverted pendulums began in the 1950s, designed by control theory experts at the Massachusetts Institute of Technology (MIT) in the United States based on the principle of rocket launch boosters. The inverted pendulum system, as the model foundation for shipborne radar, rocket launch systems, and satellite attitude control, has been the focus of many researchers in the past few decades. The research on inverted pendulums will tend towards more complex and in-depth studies. Inverted pendulum systems can be divided into linear

inverted pendulums, planar inverted pendulums, composite inverted pendulums, etc. according to their composition. According to their complexity, they can be divided into primary inverted pendulum systems, secondary inverted pendulum systems, tertiary inverted pendulum systems, and multi-level inverted pendulum systems. The first-level inverted pendulum system consists of a driving motor, a conveyor belt, a pendulum rod, a small car, and a test bench [1, 2, 3]. The first-level linear inverted pendulum system is driven by an electric motor and is an unstable, nonlinear, single-input, double-output, strongly coupled

system [4, 5, 6, 14, 15]. It controls both the angle of the pendulum and the position of the trolley to be stable, and the steady-state errors of the trolley position and pendulum angle must be controlled within a small range.

The control of the inverted pendulum is a difficult point in the study of inverted pendulum control, and there have been many studies on the inverted pendulum, which are basically based on the assumption that the trolley track of the inverted pendulum system is sufficiently long [7]. With the development of technology, new control methods are constantly emerging, and people use inverted pendulums to test whether new control methods can handle multivariable, nonlinear, and absolute instability. The inverted pendulum has become an ideal experimental method for testing the effectiveness of control strategies [8]. This article focuses on a first-order inverted pendulum system. Firstly, a mathematical model is established using the knowledge of Newtonian mechanics, and then a simulation model of the inverted pendulum system is

established using the Simulink module of MTALAB [9, 10, 11, 13]. Finally, by comparing and analyzing the curves and parameters of the established traditional PID controller and fuzzy PID controller, this study is trying to find out whether the fuzzy PID control method is better or not than the ordinary PID control method in terms of stability and speed.

II.   ESTABLISHING MATHEMATICAL MODEL

The working principle of a first-order linear inverted pendulum (Figure 1) is that when the data acquisition card transmits the collected data from the rotary encoder to the computer and compares it with the set value. The deviation is processed through some calculation, and a control law is issued to control the motor to make the pendulum swing left and right into the stable range, thereby achieving the pendulum to stand upright and not fall, as well as self-swing [12].
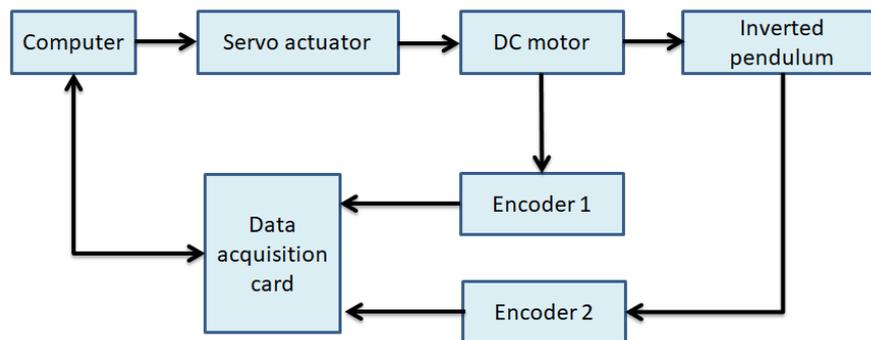
Fig.1 Working Principle Diagram of a First Level Linear Inverted Pendulum

Because establishing a mathematical model of the system is the foundation for studying control methods, the first step is to model the inverted pendulum system in this paper. And mathematical modeling is carried out using the Newtonian mechanics method to obtain the state-space equation of the system and prepare for the subsequent controller design and simulation.

The model parameters of the inverted pendulum system are the pendulum mass m_1=0.109kg, the trolley mass m_2=1.096kg g, the angle between the pendulum and the vertical direction θ (rad), the distance from the center of the swing rod to the car l=0.25m, the distance the car moves x (m), the force applied to the car f (N), the friction

coefficient of the car r_f =0.1N/m/sec, the inertia of the swing rod I=0.0034kg*m^2, and the gravitational acceleration g=9.8N/ m^2. The physical model diagram of the inverted pendulum system is shown in Figure 2. A detailed decomposition of various forces acting on the pendulum and trolley using Newtonian mechanics methods is shown in Figure 3. P and N are set as the components of the interaction force in the vertical and horizontal directions during the movement or stability of the car.
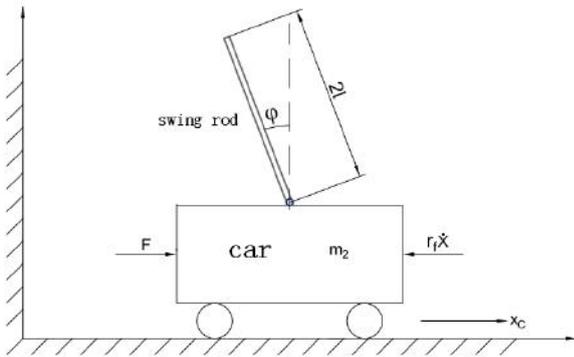
Fig.2 Physical Model of Inverted Pendulum System
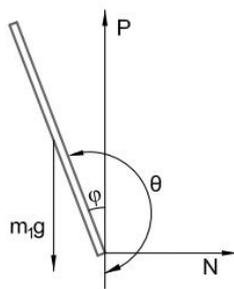
Fig.3 Force Analysis Diagram of the Small Car and Swing Rod

According to Figure 3, first analyze the force in the horizontal direction.

$$m_2\ddot{x} = F - r_f\dot{x} - N \qquad (1)$$

$$N = m_1\frac{d^2}{dt^2}(x + l\sin\theta) = m_1\ddot{x} + m_1 l\ddot{\theta}\cos\theta - m_1 l\dot{\theta}^2\sin\theta \qquad (2)$$

Substituting equation (2) into equation (1) yields the equation of motion in the horizontal direction

$$(m_1 + m_2)\ddot{x} + r_f\dot{x} + m_1 l\ddot{\theta}\cos\theta - m_1 l\dot{\theta}^2\sin\theta = F \qquad (3)$$

In the vertical direction, as the car is used as the horizontal plane, only the force acting on the swing rod needs to be analyzed to obtain

$$P - m_1 g = m_1\frac{d^2}{dt^2}(l\cos\theta) = -m_1 l\ddot{\theta}\sin\theta - m_1 l\ddot{\theta}\sin\theta - m_1 l\dot{\theta}^2\cos\theta \qquad (4)$$

The torque balance equation is

$$-Pl\sin\theta - Nl\cos\theta = I\ddot{\theta} \qquad (5)$$

The second equation of motion can be obtained by using equations (2) and (4)

$$(I + m_1 l^2)\ddot{\varphi} - m_1 gl\varphi = m_1 l\ddot{x} \qquad (6)$$

Set angle θ= π+ φ，and φ after being converted to radians, it is much less than 1 rad, that is φ ≪ 1. So it can be simplified as $\cos\theta = -1$, and $\sin\theta = -\varphi$, $\left(\frac{d\theta}{dt}\right)^2 = 0$.

Using u instead of the input force *F*, equations (3) and (6) can be simplified as:

$$\begin{cases} (I + m_1 l^2)\ddot{\varphi} - m_1 gl\varphi = m_1 l\ddot{x} \\ (m_2 + m)\ddot{x} + r_f\dot{x} - m_1 l\ddot{\varphi} = u \end{cases}$$
(7)

Perform a Laplace transform on the above equation, which will be

$$\begin{cases} (I + m_1 l^2)\Phi(s)s^2 - m_1 gl\Phi(s) = m_1 lX(s)s^2 \\ (m_2 + m)X(s)s^2 + r_f X(s)s - m_1 l\Phi(s)s^2 = U(S) \end{cases}$$
(8)

The first equation in the above equation can be written as follows:

$$\frac{\Phi(S)}{X(S)} = \frac{m_1 l s^2}{(I + m_1 l^2) - m_1 gl} \qquad (9)$$

Substitute equation (9) into the equation with the control input in equation (8), which will be

$$\frac{\phi(S)}{U(S)} =$$

$$\frac{\frac{m_1 l}{w}s^2}{s^4 + \frac{r_f(I + m_1 l^2)}{w}s^3 - \frac{(m_1 + m_2)m_1 gl}{w}s^2 - \frac{r_f m_1 gl}{w}s}$$
(10)

wherein，$w = [(m_1 + m_2)(I + m_1 l^2) - (m_1 l)^2]$。

Using equation (7) for $\ddot{x}$ and $\ddot{\varphi}$ solve, which will be

$$\begin{cases} \dot{x} = \ddot{x} \\ \ddot{x} = \frac{-(I + m_1 l^2)r_f}{(m_1 + m_2)I + m_1 m_2 l^2}\dot{x} + \frac{m_1^2 gl^2}{(m_1 + m_2)I + m_1 m_2 l^2}\varphi + \frac{(I + m_1 l^2)}{(m_1 + m_2)I + m_1 m_2 l^2}u \\ \dot{\varphi} = \ddot{\varphi} \\ \ddot{\varphi} = \frac{m_1 lr_f}{(m_1 + m_2)I + m_1 m_2 l^2}\dot{x} + \frac{m_1 gl(m_1 + m_2)}{(m_1 + m_2)I + m_1 m_2 l^2}\varphi + \frac{m_1 l}{(m_1 + m_2)I + m_1 m_2 l^2}u \end{cases}$$
(11)

Compiled into a standard state space equation as

$$\begin{bmatrix} \dot{x} \\ \ddot{x} \\ \dot{\varphi} \\ \ddot{\varphi} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & \frac{-(I + m_1 l^2)r_f}{(m_1 + m_2)I + m_1 m_2 l^2} & \frac{m_1^2 gl^2}{(m_1 + m_2)I + m_1 m_2 l^2} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{m_1 lr_f}{(m_1 + m_2)I + m_1 m_2 l^2} & \frac{m_1 gl(m_1 + m_2)}{(m_1 + m_2)I + m_1 m_2 l^2} & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \varphi \\ \dot{\varphi} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{(I + m_1 l^2)}{(m_1 + m_2)I + m_1 m_2 l^2} \\ 0 \\ \frac{m_1 l}{(m_1 + m_2)I + m_1 m_2 l^2} \end{bmatrix} u \qquad (12)$$

$$y = \begin{bmatrix} x \\ \theta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \varphi \\ \dot{\varphi} \end{bmatrix}$$

If the pendulum is regarded as a rod with uniform mass, then the inertia of the pendulum is

$$I = \frac{1}{3} m_1 l^2 \tag{13}$$

Substituting equation (13) into the first equation of equation (7) yields

$$\left(\frac{1}{3} m_1 l^2 + m_1 l^2\right) \ddot{\varphi} - m_1 g l \dot{\varphi} = m_1 l \ddot{x} \tag{14}$$

Simplify the above equation, which will be

$$\ddot{\varphi} = \frac{3g}{4l} \varphi + \frac{3}{4l} \ddot{x} \tag{15}$$

Let the system state space equation be

$$\begin{cases} \dot{X} = AX + Bu \\ Y = CX + DU \end{cases} \tag{16}$$

Let $X = [\dot{x} \quad \ddot{x} \quad \dot{\theta} \quad \ddot{\theta}], u' = \ddot{x}$, The following state space expression can be obtained

$$\begin{bmatrix} \dot{x} \\ \ddot{x} \\ \dot{\varphi} \\ \ddot{\varphi} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & \frac{3g}{4l} \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \varphi \\ \dot{\varphi} \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \\ 0 \\ \frac{3}{4l} \end{bmatrix} u' \tag{17}$$

$$Y = \begin{bmatrix} x \\ \theta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \varphi \\ \dot{\varphi} \end{bmatrix}$$

III. CONTROLLER DESIGN AND FUZZY LOGIC ESTABLISHMENT

Firstly, traditional PID is used to design PID controllers for the output displacement and output angle of the system. Through parameter tuning and control, the spatial-state equation output reaches a stable state. When studying the displacement of a small car, the spatial state control equation of the system is obtained by inputting the car parameters into equation (17) as follows:

$$\begin{cases} X = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 29.4 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0.75 \end{bmatrix} u' \\ Y = [x] = [1 \quad 0 \quad 0 \quad 0] X \end{cases} \tag{18}$$

We first use the traditional PID control method to control the spatial-state equation of displacement output and simulate it using Simulink in Matlab. We then adjust a suitable set of PID parameters through parameter tuning principles. The input is the unit step signal, and the PID parameter is $K_p = 70$, $K_I = 0.7$, $K_D = 6$ the system reaches steady state at time T=0.08S.

The fuzzy controller designed here is a two-input, three-output fuzzy PID controller, and the two output signals jointly use a fuzzy rule. The input is the error $e = r(k)-y(k)$ and error change rate $ec = e(k)-e(k-1)$ between the given value and the actual value of the car displacement or swing rod angle, and the output is the corrected values ΔK_p, ΔK_I, and ΔK_D of the PID parameters.

In this design, the basic domain of error e is taken as [-5, 5], and the basic domain of error change rate ec is taken as [-5, 5]. The domain of the output variables ΔK_p, ΔK_I, and ΔK_D are taken as [-3, 3].

In order to obtain the input of the fuzzy controller, it is necessary to fuzzify the precise quantity, that is, multiply the input quantity by the corresponding quantization factor, and convert it from the basic domain to the corresponding fuzzy domain. The quantization factor of error e is α_e=0.8, and the factor of error change rate ec is α_{ec}=0.2. The control quantity obtained through the fuzzy control algorithm is a fuzzy quantity that needs to be multiplied by a proportional factor and converted into the basic domain. When the output variable is the displacement of the car, the scaling factor of $\Delta K_p, \Delta K_I, \Delta K_D$ are $\alpha_{\Delta Kp} = \alpha_{\Delta KI} = 1, \alpha_{\Delta KD} = -5$. When taking the output variable swing angle, the scaling factor of $\Delta K_p, \Delta K_I, \Delta K_D$ are $\alpha_{\Delta Kp} = 200, \alpha_{\Delta KI} = 1, \alpha_{\Delta KD} = 30$

Divide the fuzzy domain of input variables (e, ec) and output variables $(\Delta K_p, \Delta K_I, \Delta K_D)$ into 7 fuzzy subsets, namely NB, NM, NS, ZO, PS, PM, PB representing negative big, negative medium, negative small, zero, positive small, positive medium, and positive big, respectively. The membership functions of input variables and output variables both adopt triangular membership functions, as shown in Figure 4.
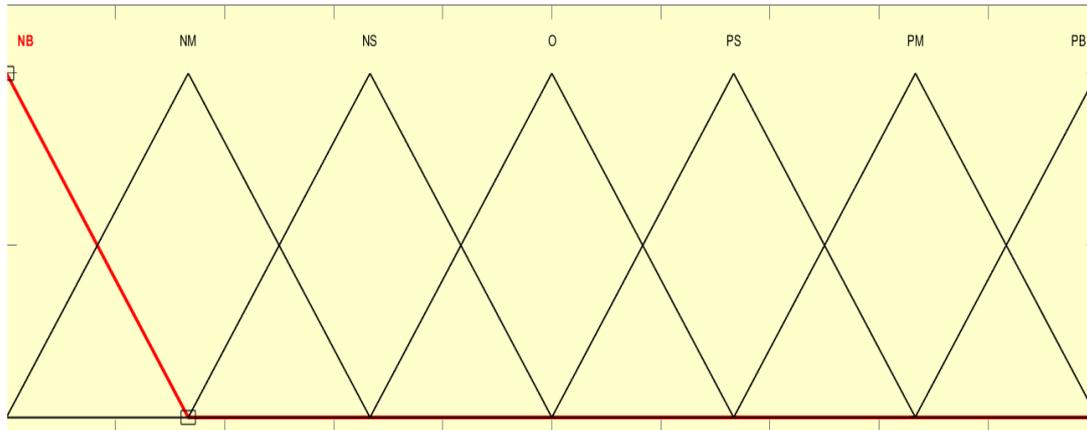
Fig.4 The Membership Function of e, ec,ΔK$_p$,ΔK$_I$,ΔK$_D$

The fuzzy rule statement used by the output variable fuzzy controller is as follows:

"**if E is**α**and EC is**β**then U is**γ" Wherein,**α,β,γ**both represent the fuzzy sets corresponding to each variable.

Based on the impact of PID parameters on system performance, parameter tuning principles, expert experience, and cognition, 49 control rules were obtained after processing, as shown in Tables 1–3.

Table 1 Fuzzy Rule Table ofΔK$_p$

K_P \ E EC	NB	NM	NS	O	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	O
NM	PB	PB	PB	PB	PM	O	O
NS	PM	PM	PM	PM	O	PS	PS
O	PM	PM	PS	O	NS	NS	NM
PS	PS	PS	O	NS	NM	NM	NM
PM	PS	O	NS	NM	NM	NM	NB
PB	O	O	NM	NM	NM	NB	NB

Table 2 Fuzzy Rule Table ofΔK$_I$

K_I \ E EC	NB	NM	NS	O	PS	PM	PB
NB	NB	NB	NM	NM	NS	O	O
NM	NB	NB	NM	NS	NS	O	O
NS	NB	NM	NS	NS	O	PS	PS
O	NM	NM	NS	O	PS	PM	PM
PS	NM	NS	O	PS	PS	PM	PB
PM	O	O	PS	NM	PM	PB	PB
PB	O	O	PS	PM	PM	PB	PB

Table 3 Fuzzy Rule Table of ΔK_D

K_D \ E EC	NB	NM	NS	O	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	O
NS	O	NS	NM	NM	NM	NS	O
O	O	NS	NS	NS	NS	NS	O
PS	O	O	O	O	O	O	O
PM	PB	PS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

This design system uses the Mamdani inference method to perform fuzzy inference on the established fuzzy rules in order to obtain control variables. Meanwhile, using the center of gravity method to solve the fuzziness of language expression, thus obtaining the exact value of $ΔK_P, ΔK_I, ΔK_D$. In addition, the values obtained through fuzzy reasoning and deblurring are multiplied by the corresponding scaling factors to obtain the incremental adjustment values of PID parameters, which are then substituted into equations (19) - (21) to obtain the control parameters of the PID controller.

$$K_P = K_{P0} + \triangle K_P \tag{19}$$

$$K_I = K_{I0} + \triangle K_I \tag{20}$$

$$K_D = K_{D0} + \triangle K_D \tag{21}$$

Before establishing a fuzzy logic controller, the Tool Box parameters of the fuzzy logic system need to be set in Simulink (Figure 5). Then use the membership function parameter setting process of Tool Box (Figure 6) to establish the membership function of $e, ec, ΔK_P, ΔK_I, ΔK_D$.
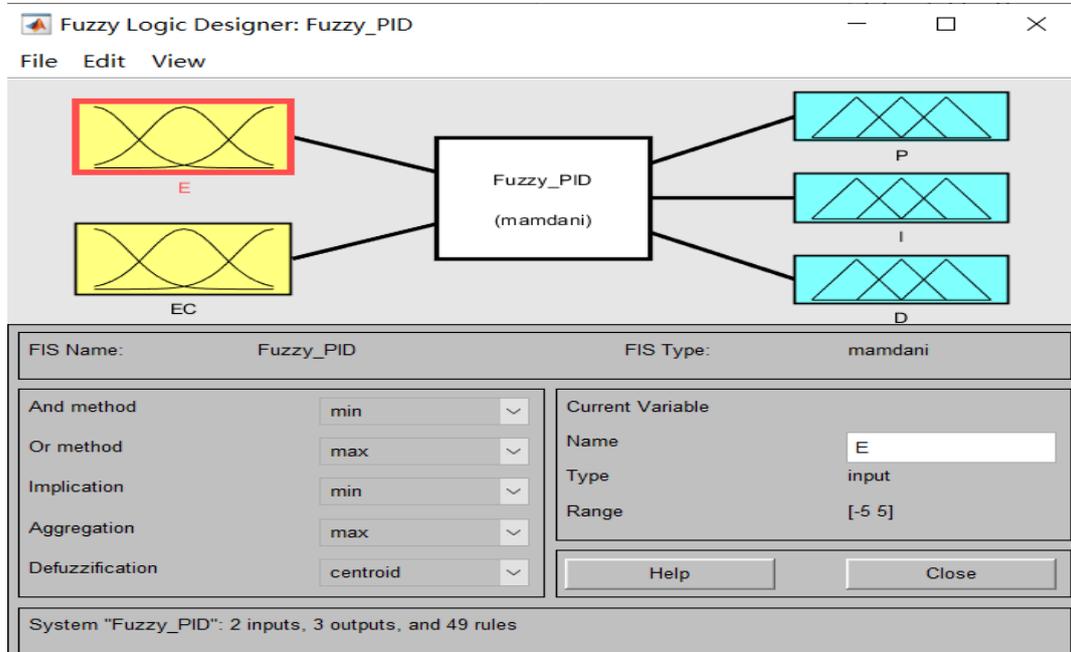
Fig.5 Fuzzy Logic System Tool Box
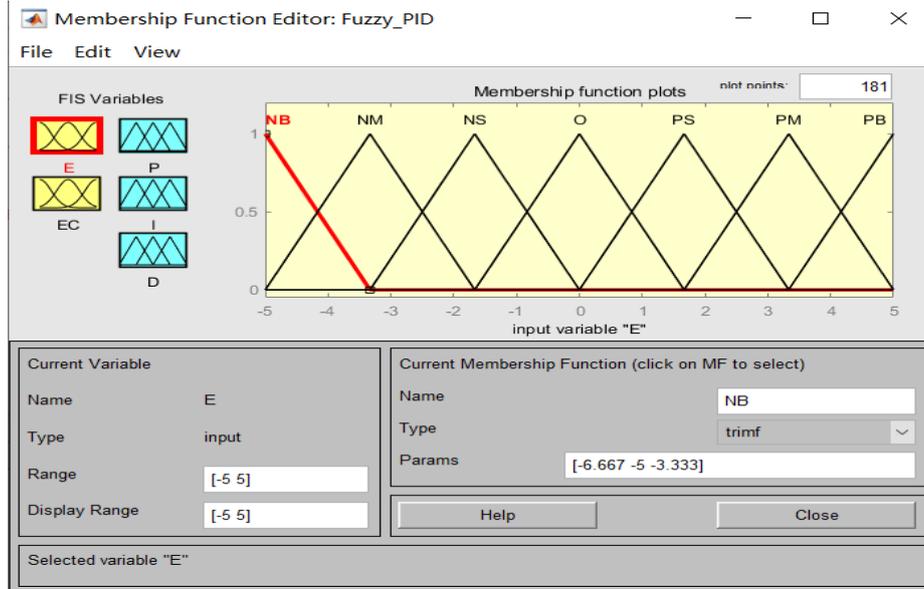
Fig.6 Membership Function of Fuzzy Logic System

After setting the above parameters, they can be added to the rule editor, and all output surfaces of the fuzzy inference system can be observed in the output surface observer.

IV. COMPARISON BETWEEN TRADITIONAL PID CONTROL AND FUZZY PID CONTROL

Through Simulink simulation (Figure 7 and Figure 8), it was found that, under appropriate parameters,

traditional PID controllers have good control effects on the control object that can assume an accurate mathematical model. They can meet the requirements of system control accuracy and rise time, but there are problems such as long adjustment times. The fuzzy PID controller can adjust the PID parameters of the system in real time. By doing so, the PID parameters can be more suitable for the control requirements of the system, resulting in better control effects than traditional PID controllers (Figure 9).
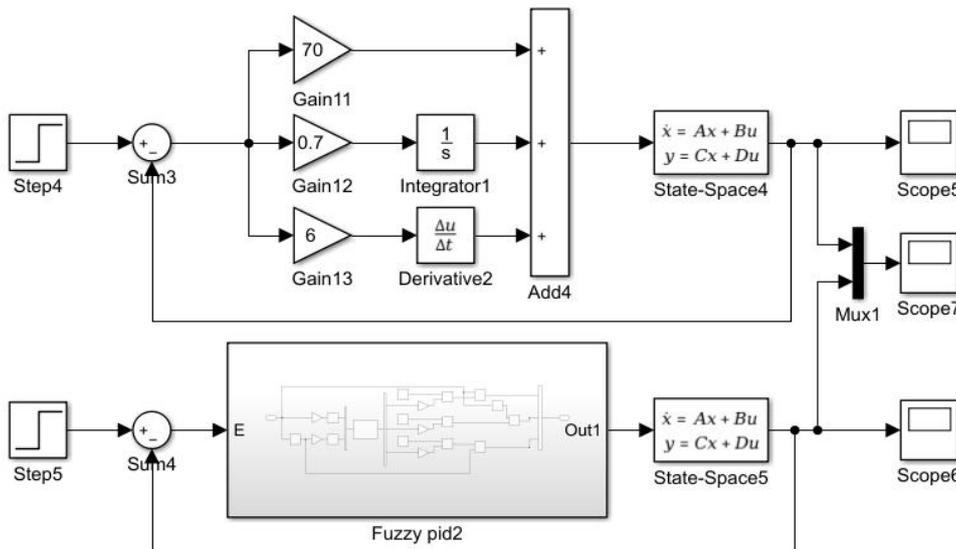
Fig.7 Simulink Simulations of Traditional PID and Fuzzy PID Control Systems (Swing Angle)
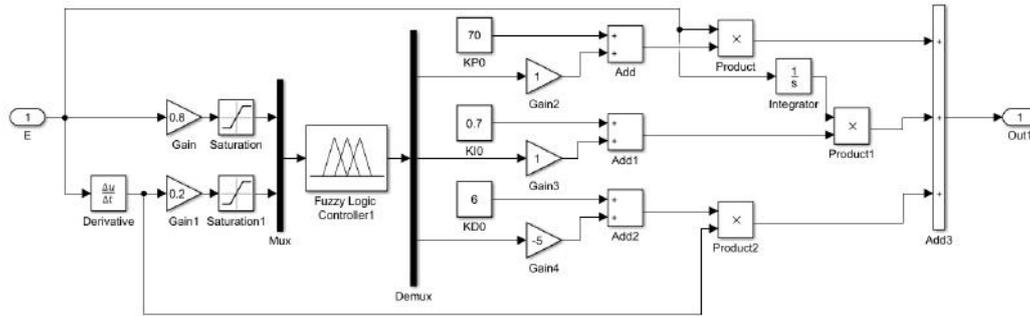
Fig.8 Simulink Simulation of a Fuzzy PID Controller for Swing Angle
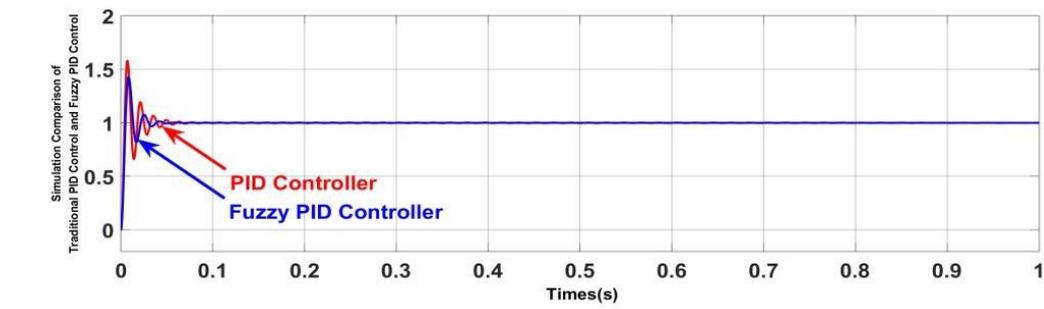
Fig.9 Response Curves of Traditional PID and Fuzzy PID Controller Systems (Swing Angle)

V. CONCLUSIONS

The inherent first-order linear inverted pendulum system is a typical single-input, multiple-output nonlinear system. This article analyzes the motion of the inherent first-order linear inverted pendulum system, establishes a mathematical model of the first-order linear inverted pendulum system using the Newtonian mechanics method, and designs PID controllers and fuzzy PID controllers to control the first-order linear inverted pendulum system separately.

By adjusting their proportional constant and integral constant, the three parameters of the differential constant enable the first-order linear inverted pendulum system to quickly and accurately reach a stable state, ultimately achieving a stable system. The superiority of fuzzy PID controllers over PID control was verified through Simulink simulation. Under the action of a fuzzy PID controller, the system has fast response speed, short adjustment time, and high steady-state accuracy, achieving the expected goals.

REFERENCES

[1] Hong, J. Research on a Level 1 Linear Inverted Pendulum Control System Based on Improved Active Disturbance Rejection Control. Anhui University of Engineering, 2019

[2] Wang, S., Zhang, F., and Chen, Z. Design of LQR controller for linear inverted pendulum. Mechanical Manufacturing and Automation, 2006, (06): 95-98

[3] Zhou, M., Miao, X., and Chen, M. Analysis and calibration of the control system for a linear inverted pendulum trolley. Electronic Testing, 2018, (09): 43-45

[4] Wang, L., and Kong, Q., Fuzzy PID control of linear inverted pendulum. Southern Agricultural Machinery, 2018, 49 (18): 83-84

[5] Wang, H., and Kong, Q. Research on PID Control of Linear Inverted Pendulum Based on MATLAB. Mechanical Engineering and Automation, 2015, (05): 179-180+182

[6] Chen, C., Zhao, Y., and Gao, J. Comparative analysis of PID and LQR control algorithms based on a single inverted pendulum. Value Engineering, 2015, 34 (18): 209-2010

[7] Xu, M., Zhou, B., and Hu, G. Simulation and experimental research on the control of a linear inverted pendulum system. Machine Tool and Hydraulic, 2018, 46 (06): 90-95.

[8] Song, S. Research on Optimization of Control Parameters of Inverted Pendulum Based on MATLAB. Electronic World, 2014, (08): 104.

[9] Luan, H., Sun, D., Sun, H., Sui, Y., and Liu, C. Design of an Assistant Teaching Example for Inverted Pendulum Control Based on Matlab. Journal of Electrical and Electronics

Teaching, 2018, 40 (04): 89-93.

[10] Zhai, L. Establishment of a Simulation Model for a Primary Inverted Pendulum. Volkswagen Technology, 2011, (08): 268-270.

[11] Ma, C., Hua, Y., and Zhou, L. Comparative Study on Control Methods of a Primary Inverted Pendulum. Computer Age, 2020, (08): 1-5+9

[12] Wang, L., Xie, Z., and Wang, Y. Research on Fuzzy Adaptive PID Control of Inverted Pendulum Based on MATLAB. Mechanical Engineering and Automation, 2020, (04): 57-58

[13] Yue, C. Control and Application of a Class of Nonlinear Under actuated Systems. Qingdao University, 2023. DOI: 10.27262/d. cnki. gqdau. 2022-002274

[14] Ashwani, K., Pravin, P., Suyashi, R., and Deepak, R. A comparison study for control and stabilization of inverted pendulum on inclined surface (IPIS) using PID and fuzzy controllers. Perspectives in Science, 2016, 8, 187-190.

[15] Ahmad, I. R., Samer, Y., and Hussain, A. R. Fuzzy-logic control of an inverted pendulum on a cart. Computers & Electrical Engineering, 2017, 61, 31-47.

Consequences and what the Risks of Automedication

Ana Karoliny dos Santos Rocha, Ana Ruth Lula Santana, Gleicy Viana de Souza, Ian Souza Santos, Jéssica Ferreira Souza, Jessica Souza Freire, Marcella Mendes de Sá, Sabrina Rodrigues Santiago, Daniel Rodrigues Silva

Abstract— *Self-medication is seen as the use of pharmaceuticals without medical advice, where patients use drugs in an irregular manner, not taking into account doses or time of correct treatment. Brazil occupies the fifth place in drug consumption in Latin America, with high rates of hospitalization and death due to overdose and intoxication. Thus, the objective of the research is to highlight the consequences and main health risks arising from the self-medication of drugs, highlighting the possibility of using drugs of lower impact from the orientation of pharmacists. Authors report that among the major problems to reduce self-medication in Brazil are the governmental problems, such as the lack of resources for the Unified Health System (SUS), and insufficient number of within doctors health units. These factors make people who go through periods of pain, seek drugs in an inappropriate way, without worrying about possible health risks. The problem of self-medication reaches even children and the elderly, who are endangered by the use of pharmaceutical drugs often incompatible with their body. An alternative to the problem is the performance of the pharmaceutical professional who can guide the correct use of the drugs, reducing risks by self-medication. However, the need to implement strategies to raise awareness among the population shows the risks to health through self-medication.*

I. INTRODUCTION

Self-medication can be defined as the use of products without medical recommendation or supervision, being characterized by the patient's own initiative in consuming pharmaceutical drugs, aiming to treat or alleviate symptoms or diseases in the promotion of health (NAVES et al., 2010; VITOR et al ., 2008).

Self-medication practices include purchasing medicines without a prescription, sharing medicines with other members of the family or social circle, reusing leftover medicines from previous treatments, using old prescriptions and prolonging a treatment indicated by the doctor (CARVALHO et al. al., 2008).

The use of indiscriminate use of medicines is considered worrying by authorities in several countries. According to the World Health Organization (WHO), the percentage of hospital admissions resulting from adverse reactions to pharmaceutical drugs exceeds 10%, as 50% of medications are incorrectly prescribed, dispensed and sold, with half of patients using them incorrectly. In Brazil, the Ministry of Health's Medicines Policy alerts the population to the risks of self-medication and seeks to raise awareness about the correct way to use these products, as the country is one of the main consumers of medicines (CASTRO et al., 2013; DOMINGUES et al., 2015).

In Brazil, the medicine market reaches 22.1 billion dollars annually, and their availability increases the possibility of irrational use, promoting health risks instead of adequate treatments. The country still ranks fifth in the

world consumption of over-the-counter drugs, being the first in Latin America (SOUZA et al., 2011).

According to Vitor et al. (2008) in some countries with a poorly structured healthcare system, going to the pharmacy represents the first option to solve a health problem. Most medicines are sold without a prescription and are easily available in pharmacies, drugstores and even supermarkets.

Among the most common symptoms resulting from self-medication are respiratory infections, headache and poor digestion. However, studies carried out show that people who use medications indiscriminately have not stopped self-medicating due to the convenience, speed of action, high tolerability over time, safety and effectiveness of the drugs (NASCIMENTO, 2003).

However, some authors report that self-medication can be carried out in a responsible and beneficial way when selected as a therapeutic alternative with the help and guidance of a pharmacist. Therefore, it may be suitable for the patient when at the appropriate dose, concentration and treatment time (CASCAES et al., 2008).

Therefore, the objective of the study is to highlight the consequences and main health risks arising from self-medication of drugs, highlighting the possibility of using lower-impact medications through the guidance of pharmacists in health promotion.

II. MATERIAL AND METHODS

To develop the study, a bibliographical survey was adopted in electronic databases, scientific books and Brazilian legislation. The databases used were: Scientific Electronic Library On-line (Scielo), Medical Literature Analysis and Retrieval System Online (MEDLINE) and journals from the Coordination for the Improvement of Higher Education Personnel (CAPES).

In order to expand the results, words in Portuguese and English were used, namely: self medication, consequence and health risk, drug utilization, pharmaceuticals and medical prescription.

To this end, the study separated main research in order to report health risks arising from the incorrect use of pharmaceutical drugs, reporting cases with children, adolescents, adults and the elderly. Research also refutes the possibility of pharmacists acting to reduce patients' self-medication with their help.

III. DISCUSSION AND RESULTS

According to the Medicines Statute published in Decree-Law nº 176/2006, medicine is understood as:

Any substance or association of substances presented as having curative or preventive properties for diseases in humans or their symptoms or that can be used or administered to humans with a view to establishing a medical diagnosis or, exerting a pharmacological, immunological or metabolic action , to restore, correct or modify physiological functions (BRASIL, 2006).

The medicine must therefore promote safety and effectiveness for the treatment of different ailments. However, in modern society, with the countless advances in science and the increase in the number of drugs, the objective of relieving pain has become a means of producing false well-being, even leading to high levels of dependence (BARROS, 1995; AQUINO et al., 2010).

In these aspects, self-medication arises, identified as the use of industrialized products without a medical prescription with the aim of treating self-recognized symptoms or health problems (SOUZA et al., 2011).

There are different reasons that lead people to self-medicate, the main one being pain. Individuals who experience a painful experience seek relief through medical advice, complementary therapies and even self-medication with drugs. A study carried out in Spain shows that of 1,964 people, of different ages and of both sexes, faced with a feeling of pain, 27.6% self-medicate, without thinking about seeking medical attention (BASSOLS et al., 2002).

In Brazil, Campos et al. (1985) reports that the lack of resources allocated to the Unified Health System (SUS), as well as the insufficient number of doctors in the units, leads people to self-medicate, considering that when they are in pain, they cannot simply ignore the fact.

Among the population that self-medicates, there are not only adults. Children, adolescents and the elderly are widely affected by the incorrect use of drugs, and these, in most cases, are not used independently, but are medicated by family members.

Regarding children's self-medication, research carried out by Beckhauser et al. (2010) when interviewing those responsible for children aged between 0 and 14 years, 77.5% responded that at some point they had already self-medicated their children, of which 63.9% reused old prescriptions or medicines they already had at home.

In other research related to children, Pereira et al. (2007) demonstrate that 56.6% of guardians have already medicated students with drugs, 51% of which were administered by mothers. Among the medications mentioned by those interviewed in the study, the authors report analgesics/antipyretics and non-hormonal anti-

inflammatory drugs (52.9%); medications that act on the respiratory tract (15.4%); gastrointestinal (9.6%) and; systemic antibiotics (8.6%).

Among the harmful effects arising from self-medication on children's health are the induction of bacterial resistance, masking of diseases and drug intoxication (GOULART et al., 2012). Implementing educational strategies, with the aim of raising awareness among parents and/or guardians about the possible risks to children's health, is extremely necessary, as incorrect use of these causes the loss of medicinal therapeutic activity, as well as jeopardizing the safety of themselves in danger (TELLES FILHO and PEREIRA JUNIOR, 2013).

In adult self-medication, the main cause is related to types of pain. Lopes (2001) reports that 23.3% of those interviewed in his research use medication for headaches; flu, cold and cough account for 24.6%; infections and inflammations 10%; 4.3% due to digestive or intestinal problems and; 3.2% with people who have insomnia, feel anxiety or tiredness.

Also according to the Institute of Research and Postgraduate Studies for the Pharmaceutical Market (ICTQ), the self-medication rate in Brazil was 76.4% in 2017, with only 23.6% consuming medication only with a medical prescription. , dentist or pharmacists. For ICTQ, the most consumed medications in adult self-medication are analgesics, anti-inflammatories, antiallergics, antibiotics and anxiolytics (ICTQ, 2016) (Figure 1).

Analgesics, which are the drugs most used in self-medication, are also prominent among the elderly, being most used to treat pain and inflammation, symptoms that are quite common at this stage. Adverse reactions arising from self-medication in the elderly are three times higher than in young people, with an annual incidence of 26 per thousand hospitalized patient beds (OLIVEIRA et al., 2012).

Cascaes et al. (2008) explain that interviewing 77 elderly people, 80.5% of them self-medicated, especially with over-the-counter medicines, such as painkillers and medicinal plants. They also state that the majority were medicated by friends, neighbors and family. For Sá et al. (2007) the most common reasons given in relation to symptoms are pain, fever, diarrhea, high blood pressure and cough, and in the study, 77.2% of elderly respondents use over-the-counter medications when they have a clinical complaint.

The disadvantages for the elderly, in addition to the risk in seeking treatments, are unnecessary expenses, delayed diagnoses that are masked by adverse symptoms, and inefficient and inadequate therapy, which can lead to

serious bacterial resistance and intoxication (OLIVEIRA et al., 2012).

For the Brazilian Association of Pharmaceutical Industries (ABIFARMA), around 80 million people self-medicate. For ABIFARMA, the main causes are the poor quality of the supply of medicines, non-compliance with the mandatory presentation of medical prescriptions, as well as the lack of information and education among the general population about the risks of self-medication (ARRAIS et al. , 1997).

One of the alternatives raised is the possibility of pharmaceutical professionals acting to reduce self-medication. The population in general has easy access to pharmacists, who are qualified to act as health agents, with a function not only of dispensing, but also being able to use their extensive knowledge in favor of the patient (VIDOTTI and HOEFLER, 2006). Therefore, qualified pharmaceutical assistance is necessary, ensuring easy access for the population to quality and safe medicines.

Self-medication guided by pharmacists is seen as an irreversible reality, being an integral part of healthcare systems. The action of pharmacists brings greater autonomy on the part of the population in promoting health and collaborates with governments to the extent that unsustainable numbers of medical consultations are avoided (CIM, 2007).

To achieve this, it is necessary that pharmacists are qualified and can provide instructions efficiently, avoiding health risks caused by medication poisoning. The name of the drug, the duration of treatment and its dose must be respected by patients to avoid complications, such as overdoses. Hudson et al. (2008) highlights that among the pharmacist's activities is the ability to provide assistance, aiming to make patients aware of the correct use of medicines when possible or to encourage the search for doctors when the individual reports more extreme pain or for long periods.

In this way, the practice of self-medication can be reduced in Brazil, however, there is a need for greater awareness among people regarding health and the risks arising from inadequate treatments, periods and doses. Without knowledge of the actions of drugs on the body, patients can suffer from overdose or intoxication, putting their lives at risk.

IV. FINAL CONSIDERATIONS

Among the most common practices for purchasing medicines is purchasing drugs without a medical prescription. In Brazil, the act of self-medication can be considered a public health problem, since children,

adolescents, adults and the elderly are affected by this type of action.

Several studies demonstrate the risks of self-medication, mainly in overdose and intoxication with inappropriate drugs, use of high doses and long periods of treatment.

Among the factors that lead people to self-medicate are the lack of resources allocated to the Unified Health System (SUS), and an insufficient number of doctors within health units. People who go through periods of pain, resort to the use of pharmaceutical drugs, often guided by family, neighbors or people in their social circle, without medical prescriptions, reuse leftover drugs from previous treatments, use old prescriptions and prolong treatments in a erroneous.

Studies state that the pharmaceutical drugs most consumed in self-medication in Brazil are analgesics, anti-inflammatories, antiallergics, antibiotics and anxiolytics, which, when used without a medical prescription, can often lead to patient hospitalization and even death.

One of the alternatives highlighted to reduce the problem of self-medication is the role of the pharmaceutical professional, who among his functions can help patients to use drugs correctly, reducing risks caused by self-medication. It is also important to highlight the need to implement strategies to raise awareness among the population, showing the health risks of self-medication, which can serve to alert people, encouraging the search for medical help or, in certain cases, the assistance of pharmacists.

REFERENCES

[1] AQUINO, DS; BARROS, JAC; SILVA, MDP Self-medication and health academics. Ciência Coletiva Health, v. 15, no. 5, p. 2533-2538, 2010.

[2] ARRAIS, PS; COELHO, HLL; BATISTA, MCDS; CARVALHO, ML; RIGHI, R.W.; ARNAU, KM Profile of self-medication in Brazil. Public Health Magazine, v. 31, no. 1, p. 71-77, 1997.

[3] BARROS, JAC Medication advertising: attack on health? São Paulo: Hucitec/Sobravime; 1995.

[4] BASSOLS, A.; BOSCH, F.; BAÑOS, JE. How does the General population treat their pain? A survey in Catalonia, Spain. Journal of Pain and Symptom Management, vol. 23, no. 4, p. 318-28, 2002.

[5] BECKHAUSER, G.; SOUZA, JM; VALGAS, C.; PIOVEZAN, AP; GALATO, D. Use of medicines in Pediatrics: the practice of self-medication in children by their guardians. Revista Paulista de Pediatria, v. 28, no. 3, p. 262-268, 2010.

[6] BRAZIL. Decree-Law No. 176/2006, of August 30th. Medicine Status. Infarmed -Office Legal It is Litigation. 257 P. Available in: <http://www.infarmed.pt/documents/15786/1068535/035-_DL_176_2006_11ALT/d2ae048e-547e-4c5c-873e-b41004b9027f>. Accessed on October 25th. 2018.

[7] CARVALHO, DC; TREVISOL, FS; MENEGALI, BT; TREVISOL, DJ Drug utilization among children aged zero to six enrolled in day care centers of Tubarão, Santa Catarina, Brazil. Revista Paulista de Pediatria, v. 26, no. 3, p. 238-44, 2008.

[8] CASCAES, EA; FALCHETTI, ML; GALATO, D. Profile of self-medication in elderly people participating in senior groups in a city in southern Brazil. Catarinense Medical Archives, v. 37, p. 63-69, 2008.

[9] CASTRO, GLG; MENDES, CMM; PEDRINI, ACR; GASPAR, DSMG; SOUSA, FCF Use of Benzodiazepines as self-medication: consequences of abusive use, dependence, pharmacovigilance and pharmacoepidemiology. Interdisciplinary Magazine, v. 6, no. 1, p. 112-123, 2013.

[10] DOMINGUES, PHF; GALVÃO, TF; ANDRADE, KRC; SÁ, PTT; SILVA, MT; PEREIRA, MG Prevalence of self-medication in the adult population of Brazil: a systematic review. Public Health Magazine, São Paulo, v. 49, no. 36, p. 1-8, 2015.

[11] GOULART, IC; CESAR, JA; GONZALEZ-CHICA, DA; NEUMANN, NA Self-medication in children under five years of age in municipalities in Pará and Piauí: prevalence and associated factors. Brazilian Journal of Maternal and Child Health, v. 12, no. 2, p. 165- 175, 2012.

[12] ICTQ. Pharmaceutical Market Research and Postgraduate Institute. Research on the Rational Use of Medicines in Brazil. Available in <http://www.ictq.com.br/component/tags/tag/19-farmaceutica>. Accessed on: 26 Oct. 2018.

[13] LOPES, NM Self-medication: some sociological reflections. Sociology, Problems and Practices, Oeiras, n. 37, 2001.

[14] NASCIMENTO, MC Medicines: threat or support to health? Rio de Janeiro: Vieira and Lent; 2003.

[15] NAVES, JOS; CASTRO, LLC; CARVALHO, CMS; MERCHAN-HAMANN, E. Self-medication: a qualitative approach to your motivations. Ciênc. Saúde Coletiva, Rio de Janeiro, v. 15, no. 1, p. 1751-1762, jun. 2010.

[16] OLIVEIRA, MA; FRANCISCO, PMSB; COSTA, KS; BARROS, MB A Self-medication in elderly people living in Campinas, São Paulo, Brazil: prevalence and associated factors. Public Health Notebook, v. 28, no. 2, p. 335-345, 2012.

[17] PEREIRA, FSVT; BUCARETCHI, F.; STEPHAN, C.; CORDEIRO, R. Self-medication in children and adolescents. Journal of Pediatrics, v. 83, no. 5, p. 453-458, 2007.

[18] SÁ, MB; BARROS, JAC; SÁ, MPBO Self-medication in the elderly in the city of Salgueiro - PE. Brazilian Journal of Epidemiology, v. 10, no. 1, p. 77-85, 2007.

[19] SOUSA, HWOS; SILVA, JL; SILVA NETO, M. The importance of the pharmaceutical professional in combating self-medication in Brazil. Electronic Pharmacy Magazine, v. 5, no. 1, p. 67-72, 2008.

Environmental Safety and Sustainability in Ghana's Gold Mining Sector

Li Yang, Lokko George William, Nguembi Ines Pamela

School of Economics and Management, Anhui University of Science and Technology, Huainan, China

Abstract— *The practice of gold mining is seeing remarkable growth and has emerged as a significant source of income for a large number of inhabitants in the geographical regions where it is carried out. However, despite the recognition of this potential, the process of extracting gold presents several challenges for everyone involved, with the safety and well-being of miners being particularly precarious. Our study aims to examine the occupational safety and health (OSH) practices utilised in Ghana's precious metals mines to provide valuable information to important stakeholders and authorities. Overall, the findings offer a comprehensive analysis of the welfare issues faced by individuals in Ghanaian gold mining communities. The foundation of our study is rooted in both theoretical and empirical investigations. We utilised a statistical methodology to sample all 110 individuals that participated in our survey. Through the implementation of a case study, we apply regression analysis and descriptive statistics to investigate the correlations among the variables and ascertain the strategies utilised to achieve a harmonious equilibrium between security, financial prosperity, and environmental sustainability. Our investigation uncovered a lack of Occupational Safety and Health (OSH) supervision of various systems. The main causes of crashes were identified as mechanical, physical, chemical, biological, auditory, ergonomic, and mental risk factors. This results in injuries, deaths, and instances of employees being absent from work. Furthermore, our study lacked references to the absence of occupational safety and health (OSH) regulations and protocols aimed at improving the extraction of precious metals. Our studies also examine the governance of the precious metals extraction project in Ghana, including its impact on the landscape, economic prosperity, and ecological stewardship. The findings indicate that there are instances of non-compliance with occupational safety and health regulations in the gold mining sector within the research region. Hence, the inquiry proposes achieving a harmonious equilibrium among safeguarding, financial prosperity, and sustainable growth. Attaining workplace health and safety requirements, boosting Ghana's economic output, and ensuring the longevity of the environment can be achieved by increasing the use of protective clothing and regularly incorporating aerial photography into governmental evaluations of gold extraction operations.*

I.   INTRODUCTION

1.1 Background

This section reviews studies on Ghana's mining industry's social and environmental sustainability strategies. Since the mining industry's social sustainability methods are usually part of CSR (Essah & Andrews, 2016), this section will also analyse them in Ghana. Social and environmental sustainability in developing nations defines a company's CSR operations, according to the literature. Thus, this section examines Ghana's large-scale mining sector's sustainability and CSR. Sustainability in South American mining has been studied (Loayza & Rigolini, 2016; Viveros, 2016). Thus, this part analyses sustainable implementation qualities using the latest research. As to Agyemang, Agyemang, Ansong, and Ansong (2017), CSR is new to the national institutional landscape but has gained popularity, especially in business. Businesses in banking, mining, and telecoms have adopted the idea by following essential statutory requirements (Agyemang et al., 2017). Oppong (2016a) says CSR initiatives often improve children, the environment, health, social entrepreneurship, and sports. This calls into question your sustainability understanding. Some of Ghana's environmental and social sustainability programmes exceed their CSR or sustainability implementation level, as shown in Table 2.4. Ghana may employ a lot of hydropower, which minimises greenhouse gas emissions. Large enterprises voluntarily disclose their energy use to global reporting organisations like the Global Reporting Initiative and ISO 14001. Table 2.4 shows that sustainability problems must be addressed during the mine's operating period upon closing. To meet Ghana's Minerals and Mining Act, 2006 (Act 703)'s minimum standards, land restoration, reforestation, and chemical spill avoidance are social sustainability initiatives (Oppong, 2016a). Social sustainability, a developing term, varies from CSR owing to its broader conceptual similarities. Ghana may overemphasise CSR implementation as self-regulatory, which may explain certain sustainability difficulties. Ghana's social sustainability efforts, according to Andrews (2016), are fragmented CSR programmes that contradict sustainable practices. CSR programmes prioritise physical initiatives above social sustainability (tangible and intangible) after mine closure owing to the operational implications of mining. According to Andrews (2016), voluntary CSR programmes threaten social sustainability in Ghana's extractive economy. Social sustainability may involve volunteer initiatives, mining-induced displacement legislation, development partnerships, and regulatory compliance processes. Multinational companies' CSR agenda limits mining stakeholders' capacity to challenge large-scale mining operations (Ross, 2017). In mining-related social problems, the state and major mining firms often oppose impacted communities and civil society organisations (Tetreault, 2020). The institutional framework of developing nations negatively impacts managerial cognition, or how managers make sense of their environment, which threatens mining regions' long-term viability. Ghana's sustainability efforts prioritise land restoration, impact reduction, and community growth. The usual CSR method for neighbourhood protection is also criticized in this study. The poor institutional structure that limits compliance monitoring and regulatory enforcement is the main cause of Ghana's sustainability implementation problems (Andrews, 2016). Thus, multinational mining companies' social sustainability strategies are more significant. The following observations provide a framework for studying social sustainability theoretically and empirically.

1.2 Historical Mining Growth In Ghana

The development of the country's economy has been considerably aided by Ghana's mining sector. The pre-colonial age, when this region had a long and rich history, saw a substantial amount of wealth coming from gold mining. Bauxite, manganese, diamonds, and most recently, oil and gas, were among the various minerals that were added to the industry over time. The most renowned of Ghana's several irreplaceable mineral resources is gold. The nation, which is the largest producer of gold in Africa, is among the top 10 producers of the metal globally. The growth of Ghana's economy, gains in foreign exchange, and export income have all been significantly influenced by the gold mining industry.

The mining sector in Ghana is governed by a legislative system that defines rules for mining operations. Mining operations are governed under the Minerals and Mining Act, 2006 (Act 703) and its further revisions. The Ministry of Lands and Natural Resources, which is also in charge of regulating the business, is responsible for developing the regulations that will ensure its long-term viability. The primary regulatory authority, the Minerals Commission, issues licenses and keeps an eye on compliance with mining laws.

The Ghanaian government has recently paid increasing attention to the need for moral and environmentally friendly mining practices. Initiatives have been taken within the mining sector to enhance CSR, community development, and environmental protection. This includes efforts to guarantee the equitable distribution of mining profits, decrease the negative environmental effects of mining operations, and promote favorable social results for individuals residing nearby. Reading the overview will

enable readers to get a context-specific understanding of the historical evolution, legal system, and economic significance of the mining industry in Ghana. The review's subsequent sections can analyze how mining has affected various facets of the Ghanaian economy using this information. Gold Since gold has been mined in Ghana for a very long time, it continues to be a significant location for mineral wealth. After South Africa, Ghana is the continent's second-largest producer of gold. The country's exports and foreign exchange earnings are greatly boosted by the export of gold. Through taxes, royalties, and earnings, it offers a sizable source of employment to the government and financial assistance.

1.3 Motivation and Contribution to the Study

The motivation and contribution to the study are essential aspects of any research, and in this case, they play a crucial role in understanding why this study on safety, financial performance, and environmental sustainability in Ghana's gold mining sector is important. the motivation for this study stems from the need to address critical issues in Ghana's gold mining sector, and its contributions include generating data and insights that inform decision-making, promote sustainability, and enhance the overall understanding of the industry's impact.

II.   LITERATURE REVIEW

2.1 THE RELEVANT LITERATURE

Appreciating the hyperlink between social obligation and trustee duties could offer a means of encouraging the minerals sector to behave appropriately. To carry out such procedures, the mining sector has to acknowledge that social accountability is not incompatible with financial prosperity (Carroll, 2015). This empirical study aimed to comprehend the links between corporate fiduciary duty owed to its stakeholders, social responsibility, environmental policies, and societal concerns among Ghanaian gold mining enterprises. We talk about the gap in the relevant literature in Chapter 2 of this study. Some of the topics that will be covered include Ghana's corporate social responsibility, the mining sector there, and its relationship to trusteeship. We concluded this section by highlighting the importance of the current inquiry and summarizing the findings from the chapter.

In the opinion of Hilson (2017), Guyana is a success case' within a handful of nations that utilized an alternate route to the development of the minerals industry. The mineral extraction sector is dominated by local modest mining firms, which has significantly aided its financial growth, but Hilson questions how the sector could have been allowed to avoid the negative effects of the resource curse.

As noted by Hilson (2017), a specific feature of gold-rich nations such as Papua New Guinea, Ghana, the Philippines, and Peru, in addition to their respective positions in extraction industries, is that gold is the main objective of mineral extraction, and the business primarily focuses on exporting its goods, which does not contribute to the social and economic advancement of these nations. In addition, he indicates that the constant international need for gold for ornamentation and investment in commodities has spurred the gold mining industry worldwide. Additionally, international donors have encouraged nations who are developing to boost their extraction sector's vulnerability to global expenditure and to enlarge the minerals sector to encourage investment and grow the global economy as a whole. Over several years, multinational mining enterprises have received exemptions from taxes and other inducements from the countries where they operate, the minerals industry has developed, and yet the financial gains have declined.

2.2 The Mining Sector in Ghana

This is the result of these operations. The mining industry in Ghana employed 12,148 people and generated G$1.24 billion ($35.4 billion) for the government in 2014, according to the Ghana Chamber of Mines (2015). Luiz and Ruplal (2013) review research results, personal license plate calculations with senior executives, and elements affecting the global mining industry to establish the characteristics of African mining operations.

2.3 Prior Studies and Research on how Mining Affects Ghana's Economy

Many studies explore Ghana's extraction-related finances. These studies evaluated how mining affects GDP, employment, fiscal responsibility, sustainable development, and social impacts. Many Ghanaian studies have addressed extraction and income growth. Using statistical methods, Amankwah and Anim-Sackey (2018) studied coal's GDP impact in Ghana. Their businesses discovered that drilling helped the economy, proving the industry's importance. The immediate and long-term consequences of quarrying on employment have been explored. Mining communities were less poor and lived better. More studies have studied how extraction impacts fiscal revenues. Ghana Revenue Authority data was used by Bawumia et al. (2015) to examine extractive industry revenues. They discovered that extraction dramatically increased constitutional tariffs, compensation, and bonuses, which supported roads and vital services. The environmental sustainability of Ghanaian extraction has been researched. Gyamfi et al. (2019) examined extractive industries' local environmental implications. Forest loss, filthy water, and soil erosion were connected to mineral

mining. The report underlined the need for strict environmental laws and eco-friendly mining technologies to mitigate these effects. Also addressed were extraction's consequences on community growth and social tensions. Many studies explore Ghana's extraction-related finances. These studies evaluated how mining affects GDP, employment, fiscal responsibility, sustainable development, and social impacts. Many Ghanaian studies have addressed extraction and income growth. Using statistical methods, Amankwah and Anim-Sackey (2018) studied coal's GDP impact in Ghana. Mining's impact on Ghana's economy is well studied. The study examined how mining sector components affected social results, employment growth, tax income, and environmental sustainability. Several empirical studies have examined Ghana's mining and economic growth. Amankwah and Anim-Sackey (2018) used econometrics to study mining's impact on Ghana's GDP. Mining drives economic growth, proving its importance. Studies have examined how mining will affect employment now and later. They discovered that mining jobs supported nearby businesses. Mining locations offer better living conditions and less poverty. Research shows mining affects tax revenues. Using Ghana Revenue Authority statistics, Bawumia et al. (2015) examined Ghana's mining industry's fiscal contributions. Their findings showed that mining increased tax revenues, royalties, and profits, funding infrastructure and public services. A Ghanaian mining study emphasises sustainability. The ecology of mining areas was explored by Gyamfi et al. (2019). Deforestation, water pollution, and soil deterioration resulted from mining. The research recommended strict environmental restrictions and ethical mining to mitigate these effects. Community development and social disagreements dominate mining social effects research. Aryee (2016) analysed Ghana's mining industry's social consequences and CSR's potential benefits. Along with infrastructural and educational developments, benefit-sharing and stakeholder participation difficulties were noticed. These past studies detailed mining's complex economic, environmental, and social repercussions on Ghana's economy and its expanding mining sector's advantages and disadvantages.

2.4.1 Mining Resource and Theory Will Impact Society

The application of the resource curse hypothesis to the Ghanaian extractive industry allows for the analysis of potential hazards and the creation of mitigating strategies. Examining the social impact the anticipated societal repercussions of growth initiatives like extractive industries are examined using a method known as social impact assessment (SIA) (IAIA, 2018). We have a solid foundation for understanding how mining has impacted

Ghana's economy thanks to these fundamental ideas and beliefs. While the concept of equitable growth concentrates on obtaining financial success while taking social and environmental variables into account, the "curse of resources" hypothesis places a particular emphasis on the dangers of drug consumption. Companies' social responsibility plays a crucial role in promoting environmentally responsible mining practices, and the assessment of social impact helps pinpoint and address the social effects of mining. Administrators, individuals involved, and mining entrepreneurs will be better able to manage Ghana's natural resources while advancing toward attaining equitable and sustainable growth by embracing the aforementioned principles and ideas.

2.5 Mining's Economic Impact

The mining sector has had a big impact on Ghana's economic development. Due in large part to gains in foreign exchange, investments, and ties to other economic sectors, the sector has significantly raised the country's GDP. Mining activity money has been crucial in fostering infrastructure growth and social service investment, both of which are essential for the advancement of the economy and the well-being of society. In addition to other developmental activities, these expenditures have aided in the development of public utilities, education and healthcare facilities, and transportation networks (World Bank, 2020; Aryee, 2016). Additionally, Ghana's industrialization and economic diversification have been sparked by the mining industry. The existence of the business has encouraged the expansion of related industries including manufacturing, construction, and transportation. The interconnection of the mining industry with other industries has increased employment possibilities and fueled global economic growth (Aryee, 2016). Ghana's economic expansion has also been aided by foreign exchange revenues from exports of mining products. Improvements are made to the country's standing in international trade, the state of its balance of payments, and the availability of resources for the importation of products and services supporting various economic activities (World Bank, 2020). Ghana's economy has benefited from the mining sector's backing of technological development and innovation. Modern tools, equipment, and knowledge are often needed for mining activities, which promotes the development and application of cutting-edge technologies. This technological transfer and its knock-on effects have the potential to increase overall productivity and competitiveness across all economic sectors (Aryee, 2016). It is crucial to keep in mind that the level of economic growth that mining contributes to might vary depending on a range of variables, such as commodity prices,

governmental regulations, and environmental sustainability. To provide long-term advantages for Ghana's economy and its people, mining requires careful management, strong legislation, and ethical standards.

2.6 Innovation in the Gold Mining Industry in Ghana

- We can increase the profitability and productivity of Ghana's gold mining sector by utilizing digital innovation. They can therefore be used to increase mechanization through automation, develop a more thorough awareness of the resource base, optimize material and equipment flow, improve failure prediction, and monitor performance in real-time.

- Our efforts to foster a respectful and safe workplace are motivated by innovation in balancing safety in the mining industry in Ghana, which includes developing a culture of care, promoting diversity, equity, and inclusion, and identifying and eliminating harmful behaviors like bullying, harassment, and discrimination that have a broader focus. While in the area of physical safety, we broadened our perspective to ensure that workers and contractors are shielded from all types of harm, including psychological. In response to growing awareness of bullying and harassment in the mining sector.

- There are five cutting-edge approaches to making the gold mining business more environmentally sustainable, and they are as follows.

- The greatest environmental dangers are associated with conventional mining methods like open pit and underground mining.

- Mining waste reuse.

- Eco-friendly machinery.

- Cleaning up Old Mines.

- Eliminating Illegal Mining.

III.   METHODOLOGY

Deductive and inductive components are combined in the research methodology. In deductive studies, the investigation is guided by the current theory and presumptions. The gathered data is then used to support or challenge the hypothesis, assisting in its revision. In a nutshell, once the empirical findings of the research are compared to the selected hypothesis, the deductive technique may include an inductive strategy. The method of deductive reasoning appears to be consistent with the research design of the study. This is demonstrated by the research's utilization of existing ideas which include the resource enchantment hypothesis, Dutch sickness hypothesis, and mine ideas.
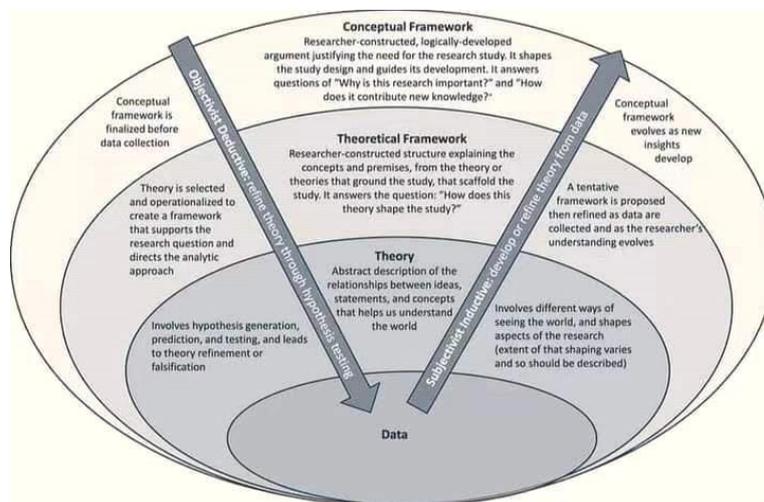
Fig.1:Different type of study we conducted

In this study, the consequences of mining on the Ghanaian economy from 1992 to 2020 were examined through a review of the literature. The study looked at how mining operations affected the economy, society, and environment to provide information to decision-makers, stakeholders, and academics.

3.1 Mathematical Model

 Our research work is based on theoretical and empirical study. In our study, we employed a statistical approach for sampling all 110 survey respondents. By doing a case study, we use regression and descriptive statistics to examine the relationships between the variables to determine the tactics employed to strike a balance between

security, financial success, and environmental sustainability. This was used due to the unclear population.

$$n_0 = \frac{Z^2 pq}{e^2}$$

- n_n =Size of the sample,
- Z^2 = the desired confidence level is abscissa of the normal curve that cuts off an area at the tails $1 - \alpha$, l, e.g., 95%,
- e is the desired degree of accuracy.
- p is the estimated percentage of an attribute that the population possesses.
- q is $1 - p$.

Where;

- $Z\ score\ =\ 1.05$
- $p\ =\ 0.5$
- $q\ =\ 1 - p$
- $e\ =\ 0.05$

Therefore;

$$n_0 = \frac{Z^2 pq}{e^2}$$

$$n_0 = \frac{(1.05)^2 (0.5)(0.5)}{(0.05)^2} = 110.25$$

The linear regression equation is:

$$y = \beta_0 + \beta_1 x + \varepsilon$$

Whereas;

Y represents what can be expected from the subject variable (y) in light of any factor in the independent variable (x).

β_0 is the intercept, or the value of y that is anticipated when x is 0.

β_1 regression coefficient

X is the independent variable (the one that we anticipate impacting y). ε is our estimate of the logistic statistic's estimation error, or how much it differs from our estimate?. With looking for the correlation parameter (β_1) which optimizes the prediction's aggregate error (ε) (Zou et al., 2003), linear regression discovers the best-fitting line through the data. Using this technique, each hypothesis was evaluated. The relationship between the uncorrelated variables as well as dependent factors was analyzed using logistic regression as well as correlation techniques. The adoption of OSH practices by smallholder coal miners was the dependent variable (y) in this section, and the independent variables (X) were sociocultural characteristics, common OSH concerns, managerial commitment, training, and demographic characteristics.

After gathering information and administration, the study began by generating descriptive data and analyzing possible difficulties with multicollinearity, heterogeneity, and oscillation. The suitableness of using random vs fixed impacts was subsequently assessed.

In order check the multicollinearity we use VIF, which is called variance inflation factor, the mathematical for calculating VIF manually is;

$$VIF_i = \frac{1}{1 - R_j}$$

Whereas, R_j is residual correlation regression.

In order to heterogeneity, we use the mathematical formula;

Mathematically, I^2 is expressed as $I^2 = \tau^2 / (\sigma^2 + \tau^2)$, where τ^2 denotes the between-trial heterogeneity, σ^2 denotes some common sampling error across trials, and $(\sigma^2 + \tau^2)$ is the total variation in the meta-analysis.

3.2 Data Collection Methods

The Ghanaian EPA, Ghana's Chamber of Mining, and local stakeholders who are now gaining from social entrepreneurship projects were included in the research's population in addition to all of Ghana's continuously operating and publicly listed gold mining enterprises. We acquired further research information for the project. In the Republic of Ghana, 14 gold mining companies—10 of which are actively engaged in stock market trading—are working on the AKOBEN Initiative.

3.3. 1 Sampling and Sampling Procedures

Using the entire population sample method, we chose ten mining firms. The complete research population was taken into account in the sampling procedure by using a complete population sampling (Leedy & Oxford, 2015). The mining businesses were selected because they had offices in Ghana that pursued gold being an asset. We needed to select samples from a large enough pool of organizations to undertake the data analytics for the project. Because this study used archive data, we could access information on ten gold mines, which we identified as a constraint while doing statistical analysis. With care, further analyses of the facts were created.

- *Data Analysis Procedures*

The study included basic arbitrary and intentional sampling approaches, in addition to a method for a descriptive study that focused on operations and mining for goldfield inspections. Additional sources of data, including journals, magazines, and the World Wide Web

were employed. Gold mining companies who agreed to take part in the research were approached. 110 people in all were questioned as part of the investigation. Targeted sampling was used to choose ten (10) employees, including two (2) each from the EPA, the Minerals Commission, the Forests Commission, the Wastewater and Water Resources Commission, and the Asutifi North District Congress. The 100 participants in the sample were chosen at random. The research team conducted interviews with key informants and field research, respectively, to collect information from significant sources and small-scale artisanal miners. The EPA, the Miners Commission, the Timber Commission, the Minerals and Water Sources Commission, and the Asutifi North Regional Assembly have all employed key informant interviews and surveys to learn more about their personnel. The people who responded as the most important informants were chosen through purposeful sampling.

> To assure the reliability and fullness of the information that was obtained, the questionnaires and guide to interviews were sequentially numbered. Respondents' confidentiality and safety were ensured, thus they felt under no need to submit information. This was used due to the unclear population.

$$n_0 = \frac{Z^2 pq}{e^2}$$

- n_n =Size of the sample,
- Z^2 = the desired confidence level is abscissa of the normal curve that cuts off an area at the tails $1 - \alpha$, l, e.g., 95%,
- e is the desired degree of accuracy.
- p is the estimated percentage of an attribute that the population possesses.
- q is $1 - p$.

Where;

- $Z\ score = 1.05$
- $p = 0.5$
- $q = 1 - p$
- $e = 0.05$

Therefore;

$$n_0 = \frac{Z^2 pq}{e^2}$$

$$n_0 = \frac{(1.05)^2 (0.5)(0.5)}{(0.05)^2} = 110.25$$

As a consequence, the collection size for competent participants and inspectors selected for the study is 110. The Statistical Program for Social Science (SPSS 20.0) was used to purify, code, and evaluate the data. 2.3.

3.4 Test the Hypothesis:

Using correlation and linear regression, the research tested the subsequent assumptions:

= There is no connection between gold mining operations and common OSHA concerns.

There is no correlation between management's resolve and mining workers' acceptance of occupational safety and health standards.

The significance (alpha) levels of 10%, 5%, and 1% were used to evaluate each hypothesis. Confidence intervals of 90%, 95%, and 99% were also used. When the P-value is below the levels of statistical significance (alpha), the hypothesis test is considered statistically significant. For the findings to be regarded as statistically significant, the confidence interval must not include the conclusion of the null hypothesis (Greenland et al., 2016). According to (Sauro, 2015), the 90% confidence level is used as technological assurance when examining questionnaire data as well as a comparability because 90% confidence for a symmetrical assertion is equivalent to 95% confidence for a biased assertion. While the research used poll results, the 90% confidence level was chosen as commercial assurance in examining the miners' reactions. According to (Sauro, 2015), the 99% confidence level is usually applied for scenarios when a poor decision might result in harm or fatalities, and the researchers applied it since poor decision-making in the gold mining sector would contribute to fatalities or serious injuries. To guarantee an elevated degree of accuracy in the opinions of the smaller-scale miners, nearly each of the precious metals processing facilities in Ntotroso traveled to collect facts. Each of the provided hypotheses was tested using confidence ranges of 90%, 95%, and 99%, with corresponding significance (alpha) values of 10%, 5%, and 1%. Correlation analysis, a statistical technique, assesses the degree of association between prevalent health and safety problems and gold mining. When there is a strong correlation between several factors, there is a meaningful relationship between them. Consequently, it may be characterized by the examination of the intensity of an association using existing statistical data (Franzese and Iuliano, 2018). The approach described here is reliant upon linear regression analysis, a form of statistics used for describing the relationship between an intervention variable and any number of independent/explanatory variables. The research project utilized metrics to evaluate the relationship. The linear regression equation is:

Whereas;

Y represents what can be expected from the subject variable in light of any factor in the independent variable .

is the intercept, or the value of that is anticipated when is 0.

regression coefficient

is the independent variable (the one that we anticipate impacting .

is our estimate of the logistic statistic's estimation error, or how much does it differ from our estimate? By looking for the correlation parameter () Linear regression discovers the best-fitting line through the data. Using this technique, each hypothesis was evaluated. The relationship between the uncorrelated variables, as well as dependent factors, was analyzed using logistic regression as well as correlation techniques. The adoption of OSH practices by smallholder coal miners was the dependent variable in this section, and the independent variables were sociocultural characteristics, common OSH concerns, managerial commitment, training, and demographic characteristics. OSH dangers posed by ASGM operations in Ghana. The risks associated with gold mining in Ghana have been assessed and published, including the psychological, mental arbitrary, auditory, natural, chemical, and other risks.

IV.   RESULTS AND ANALYSIS

Simple random and intentional sampling techniques were employed in the study, along with a descriptive research plan that concentrated on ASGM operating operations and on-site field observation. The internet, journals, and periodicals were employed as secondary data sources. We contacted ASGM operators who agreed to take part in the study. For the study, questions were asked of a total of 110 people. 100 participants for the study were chosen using simple random sampling, and ten (10) officers, including two (2) each from the Environmental Protection Agency, Minerals Commission, Forestry Commission, Water Resources Commission, and Asutifi North District Assembly, were chosen using purposeful sampling. The study used field surveys and key informant interviews to collect data from key informants and artisanal small-scale miners. The Environmental Protection Agency, the Minerals Commission, the Forestry Commission, the Water Resources Commission, and the Asutifi North District Assembly officials were interviewed as key

informants using semi-structured questionnaires. Through deliberate sampling, the key informants' respondents were selected. Key informant interviews were carried out to gain additional knowledge of the perceived effects of artisanal and small-scale gold mining as well as the functions performed by these specific regulatory authorities in the research area. To determine the challenges miners faced when implementing OSH techniques, this data was acquired. However, the questions in the field survey were primarily concerned with how OSH regulations were being applied as well as common OHS problems related to small-scale mining operations. Primary data from ASGM operational sites were gathered by the study via a survey. The survey was broken down into two sections: (a) demographic information on the respondents; and (b) data on the causes and effects of accidents that occur while ASGM operations are in place. a) OSH improvement techniques and compliance levels; b) operational activities and OSH management systems for the ASGM business in Ghana. According to the scale, 1 stood for strongly agreeing, 2 for agreeing, 3 for neither agreeing nor disagreeing, 4 for disagreeing, and 5 for strongly disagreeing. Options for not at all, Very often, Often, Indifferent, Not often, and often were also available on the Likert scale. Self-administered questionnaires were used by us. The two sets of questions that made up the questionnaires had both closed-ended and open-ended inquiries. For the closed-ended questions, respondents had to choose from a variety of answers the one that best expressed their ideas. However, there were no more options for the open-ended questions. Responses from respondents were recorded or entirely expressed in writing. Respondents had enough time to carefully consider the questions before responding, ensuring that they gave truthful answers and answered questions as they understood them. Before beginning the whole question-asking process, pretesting was done to ensure the questionnaires were correct. The interview guides and questionnaires were serially numbered to ensure the correctness and comprehensiveness of the data collected. Respondents have the freedom to withhold information because their confidentiality and privacy are guaranteed.

Table 1Information about Respondent's Demographics

Variables	Frequency	Percentages
Gender		
Male	88	80.0
Female	22	21.0

Total	110	100
Age Distribution		
25	15	13.6
26-35years	56	50.9
36-45years	29	26.3
	10	0.10
Total	110	100
Level of Education		
No Education	38	34.5
Primary School	32	29.1
JSS/JHS	20	18.18
Technical/SSS/SHS	14	12.7
Tertiary/GCE 'O' Level	6	0.1
Total	110	100
Number of years in ASGM Operations		
	18	16.4
6-10 years	30	27.3
11-15years	40	36.4
16-20years	21	19.1
Total	110	100
Valid Mining Permit		
Yes	10	0.1
No	100	90.9
Total	110	100
Source of Funding for Mining Operations		
Individual Effort	21	19.1
Loan from Financial Institution	24	21.9
Family	10	0.1
Investors gold dealers	55	0.50
Total	110	100

4.1 Industry's Daily Operations

Table 2 lists the conclusions about ASGM operational activities. 4.5% of those surveyed possessed active licenses or permits. This implies that the bulk of those who responded and were running ASGM did not possess any valid licenses or permits. (McQuilken and Hilson, 2016b)(), according to which the majority of artisanal miners lack operating money and the necessary licenses to engage in mining. According to Table 2, which details the techniques respondents used to acquire land for ASGM operations, 59% of them obtained it from family members.

Additionally, this is the most straightforward method of acquiring land for ASGM operations at Ntotroso. As a result, the vast majority of family estates now have ASGM businesses. This is in line with the findings of (Agariga et al., 2021), which demonstrate that the forest cover has been replaced by a variety of land uses, such as open vegetation, mining, settlements, etc. The other respondents (Table 2) acquired the land from either chiefs or mining companies. This backs up the judgment made by chiefs in 2019 and documented by Boafo et al.

Table 2ASGM's operational activities in Ghana

Variable	Frequency	Percentage
Have you gotten a valid permit		
Yes	10	0.1%
No	100	99.9%
Total	110	100%
From whom did you acquire land from ASGM operations		
Family	60	54.54%
Chiefs	36	32.73%
Mining companies	14	12.73%
Total	110	100%
Do you have supervisors		
Yes	80	72.3%
No	30	27.3%
Total	110	100%
Do you use explosives		
Yes	90	81.82%
No	20	18.18%
Total	110	100%
Description of the type of Mining		
Both surface and underground	110	100%
The main mineral produced by Gold	110	100%

Confidence Interval 95%

Traditional leaders are responsible for supervising mined customary areas, particularly stool lands, and they should be notified before the start of mining and paid for their assistance. The Forestry Commission's desk staff claims that in addition to purchasing land from individuals, families, or chiefs, the Commission also plays a crucial part in making sure that the territory used for ASGM activities is not close to or within any forest reserves. However, if the ASGM activity occurs outside of a forest reserve but may have an influence on valuable commercial trees, the commission will provide clearance for the removal of the trees that are located within a mining concession. According to the Water Resources Commission, neither the ASGM site nor its operations significantly affect any significant water body or resource. Information on the respondents' supervisor status is provided in Table 2, which reveals that 75.4% of them had supervisors. These managers—frequently referred to as "ghetto leaders"—direct a group of miners within a "ghetto" (mine). The majority of respondents employ

explosives in their regular activities, as shown by Table 2 as well. This supported earlier studies that showed explosives are used when the ore is hard and difficult to shatter (Mcwhorter et al., 2017). The study also made an effort to divide mining into surface mining and underground mining. Instead of limiting themselves to one sort of mining, all of the respondents engaged in both (Table 2). ASGM miners operate in both surface and underground mining.

4.2 OSH Risks

Associated with ASGM operations in Ghana Physical, psychological, ergonomic, mechanical, acoustic, biological, and chemical risks are those connected to Ghana's ASGM sector.

4.2.1 Physical Hazards

Dangers to the body According to Table 3, a result, the mean reaction value in ASGM operations is only 3.59 because there are so few fire outbreaks. Observations from the field survey show that combustible goods like fuel

(diesel and gasoline) are often held in smaller quantities within the ASGM sector as opposed to open mining sites. This explains the main cause of the ASGM industry's relative lack of fire breakouts. Additionally, the mean of the ASGM sector demonstrates that explosions at abandoned sites are not common. This may be explained by the fact that when explosives are utilized, they are not frequent. According to the research, falls from great heights are a prevalent risk in the ASGM sector. The average reaction as a result was 2.08 (Table 3). This is consistent with the findings of Nakua et al. (2019), who discovered that falls and slips are among the injuries sustained while working in the ASGM mining industry. In the ASGM sector, collapsing mine pits and stranded individuals are common issues. In this instance, the typical answer value was 2.13 (Table 3). This validates the findings of (Nakua et al., 2019) that underground miners in ASGM frequently run the risk of pit collapse due to their inability to erect concrete walls and pillars to avoid rockfalls and pit collapse. Another physical concern mentioned in the paper is flooding. Table 3 demonstrates

that during the rainy season, flooding occurs at ASGM sites. This is consistent with the results of a study by Donoghue from August 2004 that identified flooding of underground pits as a significant contributor to fatal injuries among miners. As a result, operations frequently come to a standstill, and pumping the water may take several days. The mean reaction values for miners exposed to extreme heat both underground and from the sun were 1.86 and 2.16, respectively (Table 3). Since ASGM can't erect shelters that completely enclose a site, many miners are subjected to intolerable amounts of solar heat. The investigation as a result showed that miners use handmade plastic lines to connect deep underground tunnels to temporary ventilators known as "blowers" (see Fig. 2). These improvised "blowers" hardly blast out enough air as the miners continue to toil in the sweltering heat. The study also discovered that electrocution happens frequently (Table 3). The majority of mining locations were discovered to have electrical lines that were improperly connected and may electrocute at the slightest contact.

Table 3 Hazards

Hazards	Mean	S.D.
Physical Hazards	3.49	1.13
Fire outbreaks occur at construction sites	3.29	1.20
Abandoned areas often experience explosions	2.10	1.14
Workers who are walking about an unfenced hole or climbing up or down in one experience falls.	2.10	1.31
A pit caved in because there was insufficient earth support underground.	1.45	0.68
Sites where small-scale mines were being operated were flooded during the rainy season.	1.78	1.12
During the day, employees are exposed to too much sun.	2.20	1.26
Workers are subjected to extreme heat underground	2.87	1.29
In Ghana, ASGM electrocutes workers while conducting operational tasks.	2.40	
Mechanical Hazards		
At a mine site, excavators and other mobile machinery run over workers.	3.45	1.23
The whirling elements of machinery cause abrasion to workers	2.20	1.24
Some perils could lure in or trap you	2.09	1.12
There are problems with cutting and shearing while using equipment in Ghana's ASGM.	3.10	1.18
Noise Hazards		
During blasting, drilling, milling, and other operational tasks involving the use of power plants and heavy equipment, workers are exposed to a high level of noise.	1.62	1.10
Artisanal Mining in Ghana as a Whole	1.61	
Chemical Hazards		
During operation, workers are exposed to hazardous chemicals	1.98	1.13
Smoke from diesel operating equipment's total ASGM in Ghana has accumulated.	2.45	1.09

Biological Hazards		
No nose mask or guard is used, thus employees are exposed to dust at work.	1.34	1.09
Fungi infection exists because workers are required to remain barefoot in still water while washing gold.	2.03	1.11
Because of the remoteness and stagnant water at the sites, ASGM in Ghana employees are subject to mosquito bites.	1.98	1.23
Ergonomic Hazards		
Employees are involved in heavy lifting	1.34	1.06
Workers' knee injuries result from carrying large loads	2.31	1.94
Shoulder issues are prevalent among workers	1.78	1.51
Workers experience back and waist pain	2.31	1.78
Uncomfortable working images are maintained during the ASGM operation in Ghana	3.01	1.98
Physiological Hazards		
Employees put in a lot of overtime	1.98	1.23
After putting in long hours at work, employees have appropriate interactions with their families	3.09	2.98
There is violence among the workforce at all ASGM facilities in Ghana.	3.10	1.76

4.2.2 Mechanical hazards

Table 3 displays the study's findings on mechanical dangers. The findings (mean = 3.41) demonstrate how uncommon it is for ASGM staff members to be struck by trucks, excavators, or other mobile machinery. This is because simple tools and equipment were used. Trucks, excavators, and other mobile equipment may be utilized, but not when numerous machines are running at once and could crush or run over people. The mean response value for abrasion, which was 2.13 (see Table 3), indicates that abrasion concerns are widespread. According to a field evaluation, abrasion often occurs in the rotating parts of the machinery and equipment used in mining operations. Small crushers, in contrast, are employed in ASGM and don't injure anything because they can readily pull in and trap material. Although cutting and shearing risks are listed among the mechanical hazards in the survey, ASGM enterprises do not face them, as evidenced by their mean response value of 3.09 (see Table 3). The mechanical risks found in the study were consistent with those found in (Abbasi, 2018), which showed that mining requires the use of machinery, tools, and equipment for a variety of tasks. This machinery, tools, and equipment all have the potential to sever, cut, crush, strike, or stab anyone in the machine's path because of their moving or spinning parts, sharp edges, and heated surfaces.

4.2.3 Noise

The study found that noise was an issue, and the mean response value of 1.71 (Table 3) demonstrates how pervasive it is. The primary causes of excessive noise in ASGM activities may be the machinery and equipment (see Fig. 3). The fact that large machinery is needed for ore drilling, blasting, transporting, sorting, and crushing supports Hermanus's (2007) conclusion that noise is a significant problem in the mining industry.

4.2.4 Chemical Hazards

The mean reaction value for dangerous substances was 1.77 (Table 3). According to the results of the field investigation, Mercury and Med are the key ingredients used in ASGM. Because miners spend longer time underground, they breathe in poisonous materials like mercury, which are harmful to their health even if their toxicity is not immediately apparent when they come into contact with skin. The study also found that a key source of chemical hazards faced by miners in ASGM was smoke buildup from diesel-powered equipment. The accumulation of smoke from diesel equipment suggests that it is frequently observed with a mean response score of 2.56 (Table 3). The field investigation indicated that the primary sources of smoke that miners inhaled were diesel-powered equipment such as the Chinese-made crusher ("chan fan"), compressors, excavators, and power plants. The majority of miners experienced vertigo after spending a lot of time around diesel-powered machinery, according to the field survey. The finding that miners exposed to diesel particulate matter (DPM) developed cardiovascular

dysfunction, eye and nose irritation, headache, nausea, and asthma is consistent with the findings of the Utembe et al. (2015) study.

4.2.5 Biological Hazards

Dust (mean = 2.01) continued to be a major biological hazard in almost all ASGM operations (Table 3), particularly during overburden removal, blasting, ore transportation, crushing, and even ore washing. According to a 2016 study by Bansah et al., dust is created in mining during ore drilling, ore blasting, crushing, and grinding. Since most miners do not wear masks or nasal guards, they frequently run the risk of being exposed to dust. An additional biological risk discovered was fungi infection (mean = 2.3). (Table 3), illustrating how mining-related fungal infections are a common problem for miners. The stagnant waters that are frequent at mining sites make this condition hazardous. This is in line with research (Abbasi, 2018), which demonstrates that biological risks are connected to mining activities as a result of unhygienic working conditions. Therefore, the health and safety of mineworkers are significantly impacted by limbs subjected to biological dangers such as snakebites and injuries, and exposure to bacteria, viruses, fungi, and blood-borne illnesses. Miners also experience a high rate of mosquito bites (mean = 1.61) due to the standing water and distance between mine sites (Table 3).

4.2.6 Ergonomic Hazards

When objects are lifted without assistance, lifting heavy weights (mean = 1.93) is an occupational risk that frequently affects miners (Table 3). In addition to these new types of injuries, miners also experience improper posture while working and knee, shoulder, waist, and back problems during ASGM tasks (see Table 3). Beth's (2018) findings that protracted digging, uncomfortable postures, bending down, and lifting heavy goods over long distances can all cause severe and chronic back pain were supported by the study.

4.2.7 Psychological Hazard

Table 3 (Mean = 1.98) shows that miners worked a lot of overtime. The findings of this study are congruent with those of (Abbasi, 2018), who discovered that the lengthy workweeks typical of the mining sectors can occasionally lead to psychological dangers in the mining industry. Additionally, the results demonstrate that respondents frequently communicate positively with their families, as evidenced by the mean answer value of 2.54 for adequate engagement between respondents and miners' families (Table 3). These results refute the claim made by (Abbasi, 2018) that the major psychological risks for miners are isolation and loneliness. The prevalence of violence among miners is considerable (mean = 2.5), as seen in Table 3.

Due to the rigorous and challenging nature of their work, it may be assumed that miners were using narcotics at the time. Bullying and mobbing were mentioned as two psychological issues that miners must cope with in the study (Abbasi, 2018). Pit invasions might also have a role in miners acting violently. When it is determined that a group of miners' pit has struck the gold-bearing ore that is rich in gold, invasions take place. When the owners aren't there, unauthorized individuals frequently break into the pits or infiltrate them to steal from them. Because of the regular fighting among the miners, the areas are dangerous.

4.3 Implementation of OSH Procedures by ASGM

4.3.1 Safety training

The mean response value for the question of whether the ASGM industry has a well-established safety protocol was 1.59 (Table 5), indicating that it does not. Therefore, the existence of safety measures has little impact on the adoption of OSH in the ASGM industry. This can be a result of ASGM management's general lack of consideration for developing safety measures. There were no formal safety procedures in place at almost all ASGM locations. If safety protocols are absent from the ASGM locations, they cannot affect the miners' adoption of OSH practices. For safety measures, a mean response value of 3.23 (Table 5) was discovered, indicating indifference. Since the majority of miners were illiterate and had no awareness of safety procedures, they were unable to determine whether a safety routine was necessary. This supports the conclusions of (Stephens, 2016), The mean response scores of 1.74 and 1.56, respectively, in Table 4 indicate that workers receive enough training on safety practices and how to use PPE, as well as follow-ups and refresher safety training. This demonstrates that teaching in personal protective equipment (PPE), training in safety procedures, and follow-up and refresher safety training do not affect the adoption of OSH practices by miners. The field survey found that virtually any of the venues looked at offered their personnel pre- or on-the-job training. This might be the outcome of miners believing they don't require any specialist training and that learning and training occur on the job. The mean response values for regularly recognizing and reporting safety issues as well as evaluating and resolving issues that are detected promptly were 2.07 and 2.5, respectively (Table 4), indicating not frequently. Therefore, these variables won't typically have an impact on how OSH techniques are adopted in ASGM. The average response in Table 4 for how frequently facilities and equipment are maintained before and after usage was 2.33. This shows that the ASGM doesn't always perform adequate machine and equipment repairs.

Additionally, it was said that repairs are only performed to tools and machines after they have entirely failed and are unable to be used to finish a task. Additionally, because

normal maintenance on apparatus and equipment doesn't happen very often, it won't have a big impact on how frequently ASGM's miners practice OSH.

Table 4 Safety Training

Safety Training		
A tried-and-true safety procedure is in place.	1.49	0.59
The safety protocol is appropriate.		0.59
The usage of personal protection equipment and safety procedures are adequately taught to employees.	3.01	1.10
Enough follow-up and refresher safety training is offered.	1.36	0.85
Safety issues are often recognized and reported.	2.04	0.69
Identified safety concerns are carefully evaluated and handled.	2.3	0.88
Before and after me, facilities and equipment are repaired.	2.11	0.71
Overall mean	1.99	
Cultural and Social Issues	2.22	0.74
My family is very important to me, thus I strictly follow safety regulations.	2.99	0.82
I support OSH because my community has designated me as a safety ambassador.	4.058	1.12
Overall mean	2.23	

Table 5 Correlation Analysis

	Mean	S.D.	1	2	3	4	5	6	7
Physical Hazards	2.36	0.27	0.99						
Mechanical Hazards	2.82	0.52	0.21	0.99					
Noise	1.62	0.62	0.28	0.21	0.99				
Chemical Hazards	2.16	0.23	0.22	0.28	0.22	0.99			
Biological Hazards	1.89	0.23	0.41	0.22	0.314	0.164	0.99		
Ergonomic Hazards	2.22	0.36	0.22	0.41	0.436	0.644	0.544	0.99	
Psychological Hazards	2.24	0.54	0.42	0.22	0.245	0.512	0.625	0.610	0.99

4.3.2 Social and Cultural Problems

The findings (Table 5) demonstrate how socio-cultural factors affect how well the ASGM at Ntotroso miners embrace OSH. The average response value was 4.58, which indicates that respondents regard their family so highly that they take safety concerns seriously. Because they care deeply about their families and wish to live as long as possible in excellent health, the respondents commonly say that they take safety issues seriously. Because of this, even though their work is exceedingly dangerous, they take all required procedures to ensure the

safety of their operations. This, which is an important predictor, has a substantial impact on how responders embrace OSH techniques. The mean response value for the claim that "WE take OSH seriously because my community has appointed me as a safety ambassador" was 3.03, which is considered indifferent (Table 4). Because the majority of them had not been chosen to serve as safety ambassadors in their communities, the respondents to the field survey expressed uncertainty. Does not, therefore, represent a substantial factor influencing the respondents' adoption of OSH.

Table 6: Relationship between safety education, sociocultural issues, and OSH practices adoption by miners.

OHS practices	Coefficient	Std. Error	T	Sig
Safety Instruction	0.286	0.025	3.734	0.000
Social and Cultural Problems	0.259	0.0212	3.087	0.000
Con	1.643	0.357	5.052	0.000

4.4 Sociocultural Factors and Safety Education On ASGM Miners' Adoption of OSH Practices

We evaluated the connections among safety training, sociocultural concerns, and respondents' adoption of OSH practices. Safety Training and responders' adoption of OSH practices are positively correlated, as shown in Table 5. The significance level for this positive connection is 0.01. This indicates that responders who receive more safety training are more likely to adopt OSH practices. According to Table 5, there will be a 2.78% rise in respondents' adoption of OSH practices for every 10% more safety training provided. Additionally, the adoption of OSH techniques by respondents was positively correlated with socio-cultural difficulties at a significant level of 0.01. In addition, a rise in socio-cultural concerns will cause respondents' adoption of OSH practices to rise by 2.19%. This might be explained by the importance respondents place on their families and relationships. They place a high importance on their family and will do everything in their power to provide for them. So that they can take care of others, they embrace OSH practices to stay healthy and powerful. The alternative hypothesis (), which asserts that there is a positive connection with a 99% confidence interval between safety training, sociocultural factors, and the adoption of OSH practices among miners in ASGM, is accepted in place of the null hypothesis ()).

4.5 Sustainability

These sustainability elements are seen as interconnected and should work in harmony because a company cannot compensate for a poor performance in one area with a fantastic performance in another (Viveros, 2016). The phrases "sustainability" and "sustainable development" are used interchangeably in this study to refer to long-term business strategies- and short-term scope to satisfy both current and future social expectations. The empirical data, discussion, and theoretical framework would, however, consider these two difficulties since the study analyzes solutions for social and environmental sustainability.

4.6 Social Responsibility

Due to the underlying themes in social sustainability) mapped the definitional bounds to include the following: "Development sustainability" (a) takes into consideration basic requirements, the growth of social capital, justice, equity, and other challenges; "Bridge sustainability" (B) discusses behavioral changes; (C) discusses how people actively embrace or reject such changes; and (D) discusses the preservation of socio-cultural qualities in the face of change (or what can be sustained). The aforementioned idea provides a framework for social sustainability that considers the necessity for growth, the preservation of social capital, and collaborative relationships with stakeholders who have a substantial impact on changes and transformations (Viveros, 2016). Using this more comprehensive paradigm for social sustainability, it examines how large-scale mining companies deal with societal consequences before, during, and after mine closure.

4.7 Sustainability in the Environment

To stop the loss of biological diversity as a result of our actions, it also calls for measures. The management of "waste rocks, tailings, acid mine drainage, airborne dust, and other contaminants, which are deposited on land, in the air and water" is crucial to the mining industry's environmental sustainability, according to K. Söderholm et al. (2015). For environmental sustainability in mining, climate change, biodiversity, and water are essential, claim Tost, Hitch, Chandurkar, Moser, and Feiel (2018). The following explanation emphasizes the relationship between human efforts to meet needs and initiatives to protect or improve biodiversity, water quality, and ecosystems, demonstrating how adaptable humans are to living in a dynamic balance with the environment. The aforementioned definition is used in this study to understand how large-scale mining operations preserve and replenish biological variety in the sense indicated by the environmental effect categories.

4.7.1 The Sustainability of the Environment

Some of the key environmental consequence categories include changes in biodiversity, freshwater use, acidification, ozone depletion, chemical pollution, and climate change (Dong &Hauschild, 2017). The literature also offers a variety of benchmarks or metrics for evaluating environmental sustainability. The monitoring of resource usage efficiency, including emissions, byproducts, and performance are two essential areas to

focus on, Effect indicators (calculate a company's influence on the environment, worker health, and occupational injuries), supply chain management, and supply chain sustainability. These definitional criteria and

indicators for environmental sustainability give a framework for assessing and understanding the effects of corporate operations and sustainable efforts (See Figure 5).
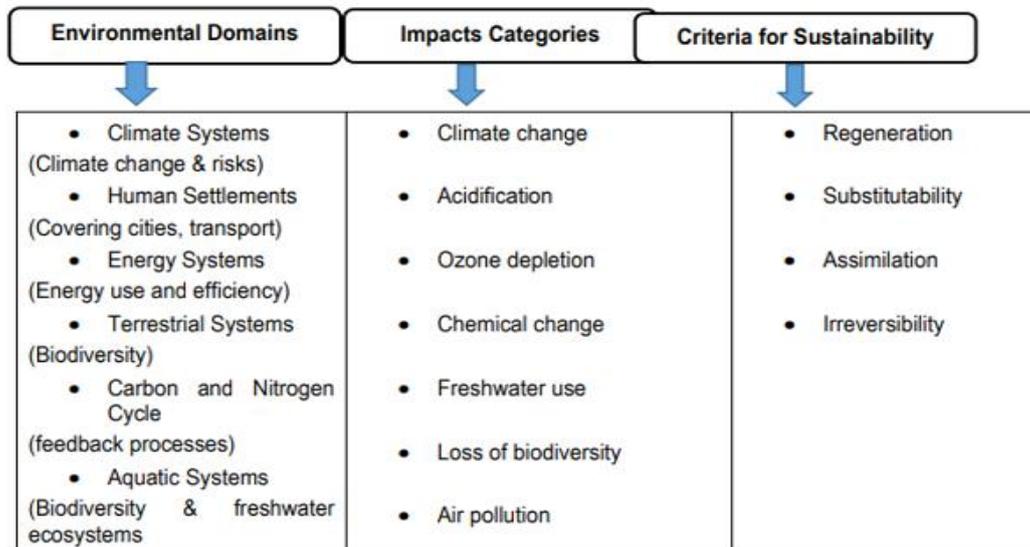
Fig.4 Environment's domain, effects, and sustainability

4.7.2 The Sustainability of the Economy

To improve a company's financial position and increase earnings, the internal component of economic sustainability focuses on using the concepts of effectiveness and efficiency in investments. Long Climate Systems & Murphy (Climate Change Risks) Energy systems (energy efficiency and consumption)

- Biodiversity in Terrestrial Systems
- The Nitrogen and Carbon Cycle (feedback mechanisms)
- Aquatic Systems: Freshwater Ecosystems and Biodiversity
- Human Settlements (including Transportation and Cities)
- Examples of environmental issues include acidification,
- Ozone depletion,
- Chemical change,
- Freshwater use,
- Biodiversity loss,
- Air pollution,
- Regeneration,
- Substitutability,
- Assimilation, and Irreversibility.

- Sustainability criteria and categories for environmental impacts.

This aspect of economic sustainability shows that consumers are more concerned about how sustainability will affect them personally than they are about a company's profits or financial performance. The economic aspect of sustainability has also drawn a lot of attention in studies on how companies increase their financial performance or look for a competitive edge (Kim, 2018). According to a similar statement, "Enterprise decision-makers naturally focus on the economic pillar of sustainability" (Hutchins, Richter, Henry, & Sutherland, 2019, p. 687). Up until recently, it was the only part of sustainability that had received attention. In addition, although the economic element of sustainability predominates, a study conducted in the metals sector by Armindo, Fonseca, Abreu, and Toldy (2019) suggests links between the various components of sustainability. However, the literature on mining shows that, despite stakeholders' primary focus on social and environmental issues, businesses still give economic sustainability a high priority (Rodrigues & Mendes, 2018). This study only considers social and environmental actions to address consequences. About the extraction of nonrenewable natural resources, sustainability is discussed in the section that follows.

4.8 Mining Environmental Sustainability

The majority of studies on sustainability in the extractive industries have focused on environmental issues, impacts, and frameworks as well as the management of the inherent risks associated with mining, according to Mensah et al. (2015), and numerous other studies. Several scholars, such as Schaltegger, Hörisch, & Freeman (2019), assert that mining firms' concerns about the consequences on the environment were ultimately what prompted them to accept sustainability as a broad phrase. Accordingly, "waste rocks, tailings, acid mine drainage, airborne dust, and other contaminants, which are deposited on land, in the air, and water" are listed as some of the negative consequences of mining on page 130 of their report by K. Söderholm et al. (2015). Tost et al. (2018) claim that to keep the environment sustainable, mining is highly reliant on elements like water, biodiversity, and climate change (see Figure 2.1).

Fig.5 Environmental sustainability and mining in the landscape

Additionally, ecological quality is sustainably improved by environmental sustainability, which also incorporates techniques for reducing the negative consequences of mining (Tost et al., 2018). In particular with large-scale or international mining businesses, these environmental sustainability plans also involve innovative technology and resource efficiency methods (Barkemeyer et al., 2015b). Therefore, environmental sustainability in developing nations continues to be significantly hampered by ambient pollution, deforestation, chemical seepages, and biodiversity loss brought on by mining activities (Mensah et al., 2015; UNDP & UN Environment, 2018). Plans for environmental sustainability also include measures to mitigate effects after mine closure due to the serious hazards connected with leaving behind lasting effects. Even though trial-and-error techniques are most frequently used, mine closure land rehabilitation typically includes

strategies for biodiversity restoration and ecosystem functioning linked to revegetation, species selection, and management of biological invasion. In contrast to the initial level of flora diversity and concentration, the process of reintroducing species is haphazard, and the amount of vegetation grown after a mine closes is always far less. However, because laws have a significant impact on mining enterprises' sustainability practices, national variations in environmental legislation may evoke different reactions depending on the institutional structure. For example, K. Söderholm et al. (2015) observe that "regulation also tends to vary from country to country depending on public policies and industry practices" about mine closure and rehabilitation. This article investigates how large-scale mining corporations adhere to environmental sustainability principles within the institutional framework, regulatory framework, and industry-led self-regulation activities of Ghana.

4.9 Ghana's CSR and Sustainability Initiatives

This section reviews studies on Ghana's mining industry's social and environmental sustainability strategies. Since the mining industry's social sustainability methods are usually part of CSR (Essah & Andrews, 2016), this section will also analyse them in Ghana. Social and environmental sustainability in developing nations defines a company's CSR operations, according to the literature. Thus, this section examines Ghana's large-scale mining sector's sustainability and CSR. Sustainability in South American mining has been studied (Loayza & Rigolini, 2016; Viveros, 2016). Thus, this part analyses sustainable implementation qualities using the latest research. As to Agyemang, Agyemang, Ansong, and Ansong (2017), CSR is new to the national institutional landscape but has gained popularity, especially in business. Businesses in banking, mining, and telecoms have adopted the idea by following essential statutory requirements (Agyemang et al., 2017). Oppong (2016a) says CSR initiatives often improve children, the environment, health, social entrepreneurship, and sports. This calls into question your sustainability understanding. Some of Ghana's environmental and social sustainability programmes exceed their CSR or sustainability implementation level, as shown in Table 2.4. Ghana may employ a lot of hydropower, which minimises greenhouse gas emissions. Large enterprises voluntarily disclose their energy use to global reporting organisations like the Global Reporting Initiative and ISO 14001. Table 2.4 shows that sustainability problems must be addressed during the mine's operating period upon closing. To meet Ghana's Minerals and Mining Act, 2006 (Act 703)'s minimum standards, land restoration, reforestation, and chemical spill avoidance are social sustainability initiatives

(Oppong, 2016a). Social sustainability, a developing term, varies from CSR owing to its broader conceptual similarities. Ghana may overemphasise CSR implementation as self-regulatory, which may explain certain sustainability difficulties. Ghana's social sustainability efforts, according to Andrews (2016), are fragmented CSR programmes that contradict sustainable actices. CSR programmes prioritise physical initiatives above social sustainability (tangible and intangible) after mine closure owing to the operational implications of mining. According to Andrews (2016), voluntary CSR programmes threaten social sustainability in Ghana's extractive economy. Social sustainability may involve volunteer initiatives, mining-induced displacement legislation, development partnerships, and regulatory compliance processes. Multinational companies' CSR agenda limits mining stakeholders' capacity to challenge large-scale mining operations (Ross, 2017). In mining-related social problems, the state and major mining firms often oppose impacted communities and civil society organisations (Tetreault, 2020). The institutional framework of developing nations negatively impacts managerial cognition, or how managers make sense of their environment, which threatens mining regions' long-term viability. Ghana's sustainability efforts prioritise land restoration, impact reduction, and community growth. The usual CSR method for neighbourhood protection is also criticised in this study. The poor institutional structure that limits compliance monitoring and regulatory enforcement is the main cause of Ghana's sustainability implementation problems (Andrews, 2016). Thus, multinational mining companies' social sustainability strategies are more significant. The following observations provide a framework for studying social sustainability theoretically and empirically.

Table 7 Domains for Environmental and Social Sustainability

Mine Lifecycle	Environmental Sustainability
Operational Phase	**Biodiversity** • Fauna and Flora **Water** • Quality and Quantity **Ambient Climate** • Air pollution • Noise pollution **Tailings Storage Management** • Chemical pollution/seepages **Energy Intensity** • Emission/greenhouse gases
Mine Closure Phase	**Lands/Biodiversity Restoration** • Vegetation regeneration potential • Animal species Richness/Diversity • Plant species richness/diversity • Habit diversity • Decreased forest land area **Water Bodies /Soil** • Destroyed or sedimented water course (surface water) • Underground water sources • Contaminated soil
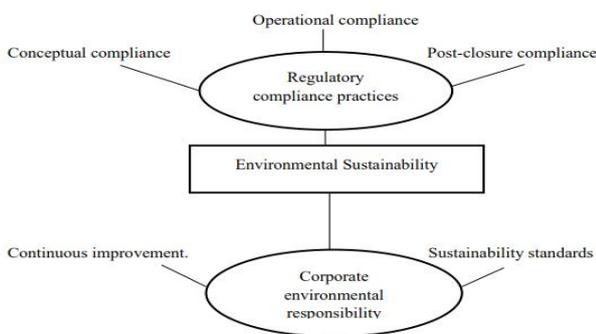
Fig.6 Environmental sustainability techniques' main topics and sub-themes Operational conformity

As previously said, mining poses significant hazards to the sustainability of the environment while it is still in operation, and managing the environmental effects of mine closure in developing nations is still very difficult. This led to the mention of "waste rocks, tailings, acid mine drainage, airborne dust, and other contaminants, which are deposited on land, in the air, and water" as examples of such mining consequences (K. Söderholm et al. 2015, p. 130). Large mining firms conduct sustainability initiatives to reduce these negative environmental effects throughout the mine's life. Although mining firms assert that their operations are beneficial to the environment, little is known about how they are addressing the short- and long-term effects of their operations. The sustainability programs that big mining corporations have implemented

to mitigate the damaging environmental effects of their operations in Ghana are examined in this chapter. To depict the main themes and sub-themes that arose from the data, thematic networks in two different implementation types are used. These sustainable practices and self-regulatory initiatives have led to these eco-friendly actions. The results presented in this chapter are set against the theme network in Figure 6. Highlighted are the key issues related to the causes that support environmental sustainability, while the sub-themes focus on how large businesses offset their consequences.

4.10 Practices for Environmental Sustainability

Selected large-scale mining companies have been profiled in this area to address environmental effects on water (quality and quantity), biodiversity, ambient climate (air and noise pollution), and soil quality. According to the statistics, impact reduction is the main goal of the environmental sustainability practices of the companies used as examples. Two crucial tools for doing this are strategies for regulatory compliance and corporate environmental responsibility. The findings demonstrate that environmental sustainability methods are applied at all stages of mining development, including pre-operational, operational, and post-operational stages. The sections that follow provide further detail on each organizational area for the methods of managing environmental effects (Figure 4.1). The table below (Table 4.1) provides a full examination of Ghana's environmental sustainability practices for controlling the consequences of mining throughout a mine's lifecycle.

Table 8 Implementing Environmental Sustainability in Ghana

Environmental sustainability practices (ESP)	Strategy	Requirement	Objective
Regulatory compliance practices 1. Conceptual	Scoping report, Environmental impact assessment,	Environmental permit, mining license	Impact mitigation
2. Operational	Compliance monitoring	EMP certification	Impact prevention
3. Post-closure	Environmental management plan (EMP)	Closure certification	Land reclamation
Corporate environmental responsibility 1. Global sustainability standards	Sustainability reporting, environmental audits and certification	Legitimation and social license	Standardization
2. Continuous improvement	Environmental charter/policy	Perceived ethical obligation	Ethical and strategic motivations

4.11 Environmental Sustainability Obstacles

To address the ecological impact requirements, which include those for ambient air quality, pollution avoidance, water and soil quality, biodiversity, and terrestrial conditions, environmental sustainability practices work to adhere to the recommendations in section 4.3. However, both the case companies chosen for the interviews and the other stakeholder groups were able to identify key themes about the shortcomings in resource governance and effect mitigation that are the principal obstacles to environmental sustainability (Figure 6). The two main problems are further divided into two sub-themes, which are deficiencies in regulatory and compliance monitoring and deficiencies in proactive and residual mitigation, as shown in Figure 6. About these themes and their sub-themes, more information is provided in the section that follows.
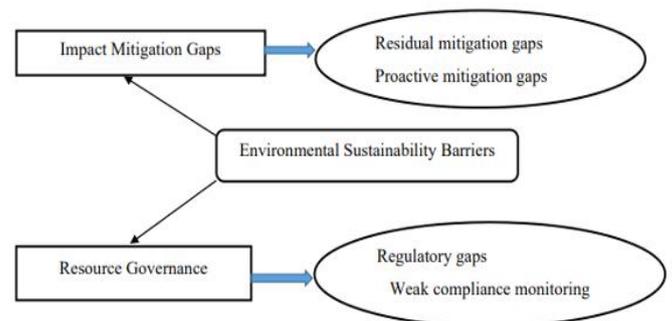
Fig.7 Implementation Challenges for Environmental Sustainability

V. CONCLUSION

Finally, we summarize the findings of our study as Gold mining, which is rapidly expanding and widely practiced throughout Sub-Saharan Africa, is an important source of earnings for a large number of people in the regions where it is conducted. Nevertheless, regardless of this acknowledged perspective, the extraction of gold presents several challenges to the individuals who partake in it, with the well-being and security of laborers being especially important. Our investigation's goal is to look at the Occupational Safety and Health (OSH) policies in Ghana's gold mining sector and reveal any flaws so that important stakeholders and authorities are aware. The overall findings of this study offer a thorough grasp of the health issues in Ghanaian gold mining villages. The research field employed a statistical approach for sampling all 110 survey respondents. The research revealed the absence of OSH system oversight, with mechanical, physical, chemical, biological, auditory, ergonomic, and psychological hazards constituting the majority of accident causes. This results in harm, deaths, and productive absences. In addition, the research revealed a lack of OSH policies and methods for improving gold extraction, for which it found no reference. In our research, we additionally deal with the way we govern the gold extraction process as it alters the countryside, as well as the economic viability and ecological conservation of Ghana. These results indicate that there have been occupational safety and health breaches in the gold rushes in the research region. Consequently, the investigation recommends striking a balance between protection, economic success, and preservation of the environment. A greater prevalence of protective clothing and footwear as well as periodic incorporation of aerial vehicles into governmental evaluations of the gold extraction industry are among the conceivable objectives for achieving occupational safety and health standards, boosting Ghana's financial health, and ensuring ecological sustainability.

REFERENCES

[1] Abbasi, S., 2018. Defining safety hazards & risks in the mining industry: a case study in the United States. Asian J. Appl. Sci. Technol. (AJAST) 2, 1071–1078.

[2] Abdulai, A.G., 2017. The Galamsey menace in Ghana: a political problem requiring political solutions. Policy Br vol. 5.

[3] Agariga, F., Abugre, S., Appiah, M., 2021. Spatio-temporal changes in land use and forest cover in the Asutifi North District of Ahafo Region of Ghana,(1986–2020). Environ. Challenges, 100209.

[4] Amoah, N., Stemn, E., Jan. 2018. Siting a centralized processing center for artisanal and small-scale mining – a spatial multi-criteria approach. J. Sustain. Min. 17 (4), 215–225. doi:10.1016/j.jsm.2018.10.001.

[5] Amoako, C., Adarkwa, K.K., Koranteng, K.A., 2021. The politics of artisanal small-scale gold mining (ASM) in the AkyemAbuakwa Traditional Area of Ghana. J. Contemp. African Stud. doi:10.1080/02589001.2021.1957791.

[6] Arthur, F., Agyemang-Duah, W., Gyasi, R.M., Yeboah, J.Y., Otieku, E., Jan. 2016. Nexus between artisanal and small-scale gold mining and livelihood in Prestea mining region, Ghana. Geogr. J. 2016, 1–18. doi:10.1155/2016/1605427.

[7] Asamoah-Gyadu, J.K., 2019. Essays on the Land, eco-theology, and Traditions in Africa.

[8] Wipf and Stock Publishers. Bansah K., Galecki G., Quaicoe I., Dumakor-Dupey N., Kenneth Joseph B., Grzegorz G., Ishmael Q., and Nelson Kofi D.-D., Occupational health and safety practices in the artisanal and small-scale gold mining sector in Ghana, 2017.

[9] Bansah, K.J., Yalley, A.B., Dumakor-Dupey, N., Jan. 01, 2016. The hazardous nature of small-scale underground mining in Ghana. J. Sustain. Min. 15 (1), 8–25. doi:10.1016/j.jsm.2016.04.004, Central Mining Institute in Katowice.

[10] Bansah, K.J., Dumakor-Dupey, N.K., Kansake, B.A., Assan, E., Bekui, P., Nov. 2018. Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. J. Clean. Prod. 202, 465–475. doi:10.1016/j.jclepro.2018.08.150.

[11] Barreto M.L., Schein P., Hinton J., and F. Hruschka, Economic contributions of artisanal and small-scale mining in Kenya: gold and gemstones, 2018.

[12] Basu, N., Clarke, E., Green, A., Calys-Tagoe, B., Chan, L., Dzodzomenyo, M., Fobil, J., Long, R.N., Neitzel, R.L., Obiri, S., Odei, E., Ovadje, L., Quansah, R., Rajaee, M., Wilson, M.L., 2015. Integrated assessment of artisanal and small-scale gold mining in Ghana-part 1: human health review. Int. J. Environ. Res. Public Health vol. 12 (no. 5), 5143–5176. doi:10.3390/ijerph120505143, MDPI.

[13] Baxter R., The future of the South African mining industry, 2015. Beth A.A., Assessment of Occupational Safety Compliance in Small-Scale Gold Mines in Siaya County, Kenya. 2018.

[14] Boafo, J., Paalo, S.A., Dotsey, S., Nov. 01, 2019. Illicit Chinese small-scale mining in Ghana: beyond institutional weakness? Sustainability (Switzerland) 11 (21). doi:10.3390/su11215943, MDPI.

[15] Franzese, M., Iuliano, A., 2018. Correlation analysis. In: Encyclopedia of Bioinformatics and Computational Biology: ABC of Bioinformatics. Elsevier, pp. 706–721. doi:10.1016/B978-0-12-809633-8.20358-0 vol. 1–3.

[16] Aryee, B. (2016). Ghana's mining sector: Its contribution to the national economy. Resources Policy, 44, 1- 10.

[17] Aryee, B. N. A. (2016). Ghana's mining sector: Its contribution to the national economy. Resources Policy, 44, 34-41.

[18] Ghana Chamber of Mines. (2020). Annual Report 2020. Ghana Chamber of Mines. (2020). Mining and Sustainable

Development Report 2019. Ghana Chamber of Mines. (2020).

[19] Ghana Environmental Protection Agency. (2019). Environmental Impact Assessment Procedures and Guidelines in Ghana. Ghana Environmental Protection Agency. (2019).

[20] Environmental performance rating and disclosure report for mining companies in Ghana. https://www.epa.gov.gh/ Ghana Environmental Protection Agency. (2019).

[21] Environmental Performance Report 2018. Ghana Extractive Industries Transparency Initiative. (2021). 2019 Mining sector report. https://gheiti.gov.gh/ Ghana Extractive Industries Transparency Initiative. (2021). 2019 Annual Progress Report. Ghana Extractive Industries Transparency Initiative. (2021). Annual Report 2021.

[22] IAIA. (2018). International Principles for Social Impact Assessment. https://www.iaia.org/uploads/pdf/SIA-Principles-2018.pdf

[23] ICMM. (2020). Enhancing Social Performance in the Mining and Metals Industry: A Compendium of Resources. International Association for Impact Assessment. (2020). What is Impact Assessment? https://www.iaia.org/ International Council on Mining and Metals (ICMM). (2020).

[24] Enhancing Social Performance in the Mining and Metals Industry: A Compendium of Resources. International Finance Corporation (IFC). (2015). Performance Standards on Environmental and Social Sustainability.

[25] World Bank. (2020). Ghana Economic Update: COVID-19, Storms, and Oil Price Shocks: Policy Options and Actions to Support a Resilient Recovery.

[26] World Bank. (2020). Ghana Mining Sector Development and Environmental Project: Environmental and Social Impact Assessment.

[27] World Bank. (2020). Ghana mining sector development and environment project. https://projects.worldbank.org/en/projects-operations/project-detail/P147862 21

[28] Abbasi, S., 2018. Defining safety hazards & risks in the mining industry: a case study in the United States. Asian J. Appl. Sci. Technol. (AJAST) 2, 1071–1078. Abdulai, A.G., 2017.

[29] The Galamsey menace in Ghana: a political problem requiring political solutions. Policy Br vol. 5. Agariga, F., Abugre, S., Appiah, M., 2021.

[30] Spatio-temporal changes in land use and forest cover in the Asutifi North District of Ahafo Region of Ghana,(1986–2020).

[31] Environ. Challenges, 100209. Amoah, N., Stemn, E., Jan. 2018.

[32] Siting a centralized processing center for artisanal and small-scale mining – a spatial multi-criteria approach. J. Sustain. Min. 17 (4), 215– 225. doi:10.1016/j.jsm.2018.10.001.

[33] Amoako, C., Adarkwa, K.K., Koranteng, K.A., 2021. The politics of artisanal small-scale gold mining (ASM) in the AkyemAbuakwa Traditional Area of Ghana. J. Contemp. African Stud. doi:10.1080/02589001.2021.1957791

[34] Arthur, F., Agyemang-Duah, W., Gyasi, R.M., Yeboah, J.Y., Otieku, E., Jan. 2016. Nexus between artisanal and small-scale gold mining and livelihood in Prestea mining region, Ghana. Geogr. J. 2016, 1–18. doi:10.1155/2016/1605427.

[35] Aryee B.N.A., Ntibery B.K., and Atorkui E., Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact, 2003. [Online]. Available: www.cleanerproduction.net

[36] Asamoah-Gyadu, J.K., 2019. Essays on the Land, ecotheology, and Traditions in Africa. Wipf and Stock Publishers. Bansah K., Galecki G., Quaicoe I., Dumakor-Dupey N., Kenneth Joseph B., Grzegorz G., Ishmael Q., and Nelson Kofi D.-D., Occupational health and safety practices in the artisanal and small-scale gold mining sector in Ghana, 2017. [Online]. Available: https://www.researchgate.net/publication/320474670

[37] Bansah, K.J., Yalley, A.B., Dumakor-Dupey, N., Jan. 01, 2016. The hazardous nature of small-scale underground mining in Ghana. J. Sustain. Min. 15 (1), 8–25. doi:10.1016/j.jsm.2016.04.004,

[38] Central Mining Institute in Katowice. Bansah, K.J., Dumakor-Dupey, N.K., Kansake, B.A., Assan, E., Bekui, P., Nov. 2018. Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. J. Clean. Prod. 202, 465–475. doi:10.1016/j.jclepro.2018.08.150.

[39] Barreto M.L., Schein P., Hinton J., and F. Hruschka, Economic contributions of artisanal and small-scale mining in Kenya: gold and gemstones, 2018.

[40] Basu, N., Clarke, E., Green, A., Calys-Tagoe, B., Chan, L., Dzodzomenyo, M., Fobil, J., Long, R.N., Neitzel, R.L., Obiri, S., Odei, E., Ovadje, L., Quansah, R., Rajaee, M., Wilson, M.L., 2015. Integrated assessment of artisanal and small-scale gold mining in Ghana-part 1: human health review. Int. J. Environ. Res. Public Health vol. 12 (no. 5), 5143–5176. doi:10.3390/ijerph120505143, MDPI.

[41] Baxter R., The future of the South African mining industry, 2015. Beth A.A., Assessment of Occupational Safety Compliance in Small-Scale Gold Mines in Siaya County, Kenya. 2018.

[42] Boafo, J., Paalo, S.A., Dotsey, S., Nov. 01, 2019. Illicit Chinese small-scale mining in Ghana: beyond institutional weakness? Sustainability (Switzerland) 11 (21). doi:10.3390/su11215943, MDPI.

[43] Health studies in the context of artisanal and small-scale mining: a scoping review. Int. J. Environ. Res. Public Health vol. 18 (no. 4), 1–24. doi:10.3390/ijerph18041555, MDPI AG, ppFeb. 02.

[44] Eshun, P.A., Okyere, E., Jun. 2017. Assessment of the challenges in policy implementation in the small scale gold mining sector in Ghana – a case study. Ghana Min. J. 17 (1), 54–63. doi:10.4314/gm.v17i1.6.

[45] Franzese, M., Iuliano, A., 2018. Correlation analysis. In: Encyclopedia of Bioinformatics and Computational Biology: ABC of Bioinformatics. Elsevier, pp. 706–721. doi:10.1016/B978-0-12-809633-8.20358-0 vol. 1–3.

[46] Apr. 2016. Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. Eur. J. Epidemiol. 31 (4), 337–350. doi:10.1007/s10654-016-0149-3.

[47] Hilson, G., Hilson, A., Maconachie, R., Jun. 2018. Opportunity or necessity? Conceptualizing entrepreneurship at African small-scale mines. Technol. Forecast. Soc. Change 131, 286–302. doi:10.1016/j.techfore.2017.12.008.

[48] Kwofie, P.S., 2015. University of Mines and Technology (UMaT), Tarkwa. Ghana - Welcome to University of Mines and Technology, Tarkwa - UMaT Hands Over Training Manuals to GNASSM http://www.umat.edu.gh/media-press/ happenings/news-events/408-umat-hands-over-training-manuals-to-gnassm.html.

[49] Mcwhorter W.B., Appiah-Opoku S., Weber J., and Jones S., Exploring the potential health and safety issues of artisanal and small-scale gold mining in Ghana; A case study, 2017.

[50] MyjoyOnline, We need a deputy minister - small-scale miners appeal, Mar. 31, 2015. https://www.modernghana.com/amp/news/608372/we-need-a-deputy-ministersmall-scale-miners.html (accessed Dec. 28, 2021).

[51] Sauro J., How confident do you need to be in your research, Retrieved April, vol. 25, p. 2015, 2015.

[52] stats, Statistical release P0441 Gross domestic product first quarter 2017, 2017. [Online]. Available: www.statssa.gov.za

[53] Siabi K., Ebenezer, Kabobah T., Amos, Akpoti, Komlavi, Geophery K., Anornu, AmoBoateng, Mark, Nyantakyi K., Emmanuel, 2021. Statistical downscaling of global circulation models to assess future climate changes in the Black Volta basin of Ghana. Environmental Challenges 5 (00299). doi:10.1016/j.envc.2021.100299.

[54] Stemn, E., Amoh, P.O., Joe-Asare, T., Dec. 2021. Analysis of artisanal and small-scale gold mining accidents and fatalities in Ghana. Resour. Policy 74. doi:10.1016/j.resourpol.2021.102295.

[55] Stephens D.K., An assessment of occupational health and safety uptake among artisanal miners in Ghana, 2016.

[56] Utembe, W., Faustman, E.M., Matatiele, P., Gulumian, M., Dec. 2015. Hazards identified and the need for health risk assessment in the South African mining industry. Hum. Exp. Toxicol. 34 (12), 1212–1221. doi:10.1177/0960327115600370.

[57] Wilson, M.L., Renne, E., Roncoli, C., Agyei-Baffour, P., Tenkorang, E.Y., Jul. 15, 2015. Integrated assessment of artisanal and small-scale gold mining in Ghana — part 3: social sciences and economics. Int. J. Environ. Res. Public Health 12 (7), 8133–8156. doi:10.3390/ijerph120708133, MDPI.

Fixed Point Results for Single-valued Mappings on a Set with Two Metrics using a Dass Gupta-type Bilateral Contraction

Amber Saeed[1], Jawad Ahmed[1], Muqddas Shabbir[1] Muhammad Umair[1], Hossain MD Sabbir[2], Shimul Paul[2], Mohammad Arfan[2], Sheikh Muktadirul Houqe[2], Hossain Anowar[2]

[1]International Islamic University, Islamabad, Pakistan
[2]Jiangsu Normal University, Xuzhou, China

Abstract— The purpose of this paper is to explore some new fixed point results using a bilateral contraction. The first thing we need to do is recall the work on fixed-point results that have been done in different research papers. By combining the results of two papers, the first was by Rus [12], which discussed different fixed point results on a set with two metrics, and the second was by Chen [4], which used bilateral contractions to prove different fixed point results. In this paper, we present new results for single-valued mappings on a single set with two metrics. In order to accomplish all of this, a bilateral contraction of the type used by Dass Gupta has been used.

NTRODUCTION AND PRELIMINARIES

In a variety of branches of mathematics, fixed point theory provides important aspects to solve problems. During the last five decades, fixed point theory has grown in popularity [1]. A metric space is a non-empty set with metric (or distance function) defined on it. There is much use of metric spaces in different fields and applications, so it is expanded in many ways [2] [3] [5] [9] [16]. In [6] Zhang and Huang explained cone metric spaces. They briefly explained Banach's fixed point theorem for such spaces. Banach's fixed point theorem explains the conditions for the uniqueness of fixed points.

Maia [10], in 1968 investigated the famous result of the Banach contraction principle using two metrics on a non-empty set. Iseki [7], in 1975 described a fixed point theorem in a metric space. Rus [12], in 1977 proved a fixed point theorem in a set containing two metrics. Sigh and Pant [14], in 1981 proved a fixed point theorem in two metrics. Kaneko and Sessa [8], in 1989, established an idea about a fixed point theorem for contractive single and multivalued mappings. Takahashi [13], in 1996, introduced a fixed point of the multivalued mappings in convex metric spaces. Muresan [11], in 2007, gave some results about the fixed point theorem of Maia and expressed how to use these results in the sets with two metrics. Joonaghany and Karapinar [4], in 2019, enhanced the composition by combining the execution of results of two bilateral contractions; which includes Dass Gupta-type bilateral contraction. Stinson, Almuthaybiri and Tisdell [15], in 2020, described a notation about the development of fixed point theorems in a set containing two metrics with the help of iterated method.

As we begin, we define a Dass Gupta-type bilateral contraction, which is cited in a well-known paper by Chen [4].

Definition 1. Let (S, ρ) be a non-empty set. The function $F : S \to S$ is called Dass Gupta-type bilateral contraction, if there is a $\phi : S \to [0, \infty)$ such that for all distinct $u, v \in S$

$$\rho(u, Fu) > 0$$

implies

$$\rho(Fu, Fv) \leq [\phi(u) - \phi(Fu)] \cdot \max\left\{\rho(u, v), \frac{[1 + \rho(u, Fu)] \cdot \rho(v, Fv)}{1 + \rho(u, v)}\right\}$$

Firstly, suppose that $\max\{\rho(u, v), \rho(v, Fv)\} = \rho(u, v)$ then take a set with two metrics, and we make the new result, which is:

Theorem 1. Let S be a non-empty set. Suppose ρ_1 and ρ_2 be two metrics on S and $F : (S, \rho_1) \to (S, \rho_1)$ be a function. If there is a $\phi : S \to [0, \infty)$ and for all $u, v \in S$

    (a) $\rho_1(Fu, Fv) \leq [\phi(u) - \phi(Fu)] \cdot \rho_2(u, v)$
    (b) (S, ρ_1) is a complete metric space
    (c) $F : (S, \rho_1) \to (S, \rho_1)$ is continuous
    (d) $\exists\ \mu \in (0, 1)$ we have $\rho_2(Fu, Fv) \leq \mu \cdot \rho_2(u, v)$

Then F has a unique fixed point.

Proof. We prove the theorem by the iterative method. For any $u \in S$, let

$$u_0 = u$$
$$u_1 = Fu_0$$
$$u_2 = Fu_1$$
$$\ldots \ldots \ldots$$
$$\ldots \ldots \ldots$$
$$\ldots \ldots \ldots$$
$$u_p = Fu_{p-1}$$

where $p \in \mathbb{N}$.

This implies that $\{u_p\}$ converges in S.

If $u_p = Fu_p$ then our theorem has been proved.

Suppose $u_p \neq Fu_p$. Then for any distinct $u_{p-1}, u_p \in S$, let $\tau_p = \rho_1(u_{p-1}, u_p)$ then by the given condition

$$\tau_{p+1} = \rho_1(u_p, u_{p+1})$$
$$= \rho_1(Fu_{p-1}, Fu_p)$$
$$\leq [\phi(u_{p-1}) - \phi(Fu_{p-1})] \cdot \rho_2(u_{p-1}, u_p)$$
$$= [\phi(u_p - 1) - \phi(u_p)] \cdot \rho_2(u_{p-1}, u_p)$$

It follows

$$\frac{\rho_1(u_1, u_{p+1})}{\rho_2(u_{p-1}, u_p)} \leq \phi(u_{p-1}) - \phi(u_p)$$

$$0 < \frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_{p-1}, u_p)} \leq \phi(u_{p-1}) - \phi(u_p)$$

$$0 < \phi(u_{p-1}) - \phi(u_p)$$

$$\phi(u_{p-1}) > \phi(u_p)$$

We conclude that the sequence $\{\phi(u_p)\}$ is not only strictly decreasing but also necessarily positive. So $\{\phi(u_p)\}$ converges to some limit $l \geq 0$.

Now for each $p \in \mathbb{N}$ we have

$$\sum_{i=1}^{p} \frac{\rho_1(u_i, u_{i+1})}{\rho_2(u_{i-1}, u_i)} \leq \sum_{i=1}^{p} [\phi(u_{i-1}) - \phi(u_i)]$$

$$\leq [\phi(u_0) - \phi(u_1)] + [\phi(u_1) - \phi(u_2)] + \cdots + [\phi(u_{p-1}) - \phi(u_p)]$$

$$\leq \phi(u_0) - \phi(u_1) + \phi(u_1) - \phi(u_2) + \phi(u_2) + \cdots - \phi(u_{p-1}) + \phi(u_{p-1}) - \phi(u_p)$$

$$\leq \phi(u_0) - \phi(u_p)$$

If $p \to \infty$ then $\phi(u_p) \to l$

$$\sum_{i=1}^{p} \frac{\rho_1(u_i, u_{i+1})}{\rho_2(u_{i-1}, u_i)} \leq \phi(u_0) - l < \infty$$

In other words, we can say $\sum_{i=1}^{\infty} \frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_{p-1}, u_p)}$ is a finite positive number.

By induction, $\frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_{p-1}, u_p)}$ is bounded in $(0, 1)$, then there exists some $\mu \in (0, 1)$ we have

$$\frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_{p-1}, u_p)} \leq \mu$$

$$\rho_1(u_p, u_{p+1}) \leq \mu \cdot \rho_2(u_{p-1}, u_p)$$

$$\leq \mu^2 \cdot \rho_2(u_{p-2}, u_{p-1})$$

$$\leq \mu^3 \cdot \rho_2(u_{p-3}, u_{p-2})$$

$$\ldots \ldots \ldots$$

$$\ldots \ldots \ldots$$

$$\ldots \ldots \ldots$$

$$\leq \mu^p \cdot \rho_2(u_0, u_1)$$

Now, for each $p, q \in \mathbb{N}$ with $p < q$ such that

$$\rho_1(u_p, u_q) \leq [\phi(u_p) - \phi(Fu_p)] \cdot \rho_2(u_{p-1}, u_{q-1})$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu \cdot \rho_2(u_{p-2}, u_{q-2})$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu^2 \cdot \rho_2(u_{p-3}, u_{q-3})$$

$$\ldots \ldots \ldots$$

$$\ldots \ldots \ldots$$

$$\ldots \ldots \ldots$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu^{p-1} \cdot \rho_2(u_0, u_{q-p})$$

Since, $\phi(u_p)$ is strictly decreasing, then $[\phi(u_p) - \phi(u_{p+1})]$ is very small and $\mu \in (0, 1)$ then we can conclude that $[\phi(u_p) - \phi(u_{p+1})]\mu^{p-1} < \epsilon$ then

$$\rho_1(u_p, u_q) < \epsilon \cdot \rho_2(u_0, u_{q-p})$$

$$< \epsilon$$

This implies that $\{u_p\}$ is the Cauchy sequence.

Since S is complete. By the continuity of $: (S, \rho_1) \to (S, \rho_1)$, for any $u_0 \in S$

$$u_0 = \lim_{p \to \infty} [F^p(u_0)]$$

$$= \lim_{p \to \infty} [F \cdot F^{p-1}(u_0)]$$

$$= F \left(\lim_{p \to \infty} [F^{p-1}(u_0)] \right)$$

$$= F(u_0)$$

Thus, $u_0 \in S$ is a fixed point of F.

Suppose $v_0 \in S$ is another fixed point of F, then

$$\rho_2(u_0, v_0) = \rho(Fu_0, Fv_0)$$

$$\leq u \cdot \rho_2(u_0, v_0)$$

$$(1 - \mu) \cdot \rho_2(u_0, v_0) \leq 0$$

$$\rho_2(u_0, v_0) = 0$$

$$u_0 = v_0$$

Hence, u_0 is a unique fixed point of F.

By applying some more conditions to the above theorem, we make a new result. More conditions were taken from the paper by Rus [12].

Theorem 2. Let S be a non-empty set. Suppose ρ_1 and ρ_2 be two metrics on S and F, $F_p : S \to S$ be the functions. If for all $u, v \in S$ such that

(a) (S, ρ_1), (S, ρ_2) and F satisfy the hypothesis of Theorem 1

(b)   The sequence F_p uniformly converges on (S, ρ_1) to F

(c) $\exists \; \lambda > 0$ we have $\rho_2(u, v) \leq \lambda \cdot \rho_1(u, v)$

Then for every $u_p \in S$, sequence $\{u_p\}$ converges to a unique fixed point u_0 of F.

Proof. We prove that every sequence $\{u_p\} \subseteq S$ converges to a unique fixed point $u_0 \in S$. Since for some $p \in \mathbb{N}$

$$F^p(u_p) = u_p$$

Now,

$$\rho_1(u_p, u_0) = \rho_1 \left(F_p^2(u_p), F^2(u_0) \right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + \rho_1 \left(F^2(u_p), F^2(u_0) \right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(Fu_p)] \cdot \rho_2 \left(F^2(u_p), F^2(u_0) \right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(Fu_p)]\mu \cdot \rho_2(u_p, u_0)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(Fu_p)]\mu\lambda \cdot \rho_1(u_p, u_0)$$

Since

$$[\phi(u_p) - \phi(Fu_p)]\mu\lambda < 1$$

$$=> [\phi(u_p) - \phi(Fu_p)]\mu\lambda \to 0$$

$$=> [\phi(u_p) - \phi(Fu_p)]\mu\lambda < \epsilon$$

Then

$$\rho_1(u_p, u_0) \leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + \epsilon \cdot \rho_1(u_p, u_0)$$

$$(1 - \epsilon) \cdot \rho_1\big(u_p, u_0\big) \leq \rho_1\left(F_p^2(u_p), F^2(u_p)\right)$$

$$\rho_1\big(u_p, u_0\big) \leq (1 - \epsilon)^{-1} \cdot \rho_1\left(F_p^2(u_p), F^2(u_p)\right)$$

$$\leq (1 - \epsilon)^{-1} \cdot \left[\rho_1\left(F_p^2(u_p), F \cdot F_p(u_p)\right) + \rho_1\left(F \cdot F_p(u_p), F^2(u_p)\right)\right]$$

$$\leq (1 - \epsilon)^{-1} \cdot \left[\rho_1\left(F_p^2(u_p), F \cdot F_p(u_p)\right) + \epsilon_1 \cdot \rho_1\left(F_p(u_p), F(u_p)\right)\right]$$

It is given that F_p uniformly converges to F in metric ρ_1, then $\rho_1\left(F_p^2(u_p), F \cdot F_p(u_p)\right) \to 0$ and $\rho_1\left(F_p(u_p), F(u_p)\right) \to 0$ as $p \to \infty$. Thus

$$\rho_1\big(u_p, u_0\big) \leq (1 - \epsilon)^{-1} \cdot \left[\rho_1\left(F_p^2(u_p), F \cdot F_p(u_p)\right) + \epsilon_1 \cdot \rho_1\left(F_p(u_p), F(u_p)\right)\right] \to 0$$

It means

$$\rho_1\big(u_p, u_0\big) \to 0$$

as $p \to \infty$.

Hence, $\{u_p\}$ converges in (S, ρ_1) to a unique fixed point u_0 of F.

Now, suppose in the definition-1, if $\max\{\rho(u, v), \rho(v, Fv)\} = \frac{[1 + \rho(u, Fu)] \cdot \rho(v, Fv)}{1 + \rho(u, v)}$ then one more new result is generated.

Theorem 3 Let S be a non-empty set. Suppose ρ_1 and ρ_2 be two metrics on S and $F : (S, \rho_1) \to (S, \rho_1)$ be a function. If there is a $\phi : S \to [0, \infty)$ and for all $u, v \in S$ such that

(a) $\rho_1(Fu, Fv) \leq [\phi(u) - \phi(Fu)] \cdot \frac{[1 + \rho_2(u, Fu)] \cdot \rho_2(v, Fv)}{1 + \rho_2(u, v)}$

(b) (S, ρ_1) is a complete metric space

(c) $F : (S, \rho_1) \to (S, \rho_1)$ is continuous

(d) $\exists\ \mu \in (0, 1)$ we have $\rho_2(Fu, Fv) \leq \mu \cdot \rho_2(u, v)$

Then F has a unique fixed point.

Proof. We prove the theorem by the iterative method. For any $u \in S$, let

$$u_0 = u$$
$$u_1 = Fu_0$$
$$u_2 = Fu_1$$
$$\dots \dots \dots$$
$$\dots \dots \dots$$
$$\dots \dots \dots$$
$$u_p = Fu_{p-1}$$

where $p \in \mathbb{N}$.

This implies that $\{u_p\}$ converges in S.

If $u_p = Fu_p$ then our theorem has been proved.

Suppose $u_p \neq Fu_p$. Then for any distinct $u_{p-1}, u_p \in S$, let $\tau_p = \rho_1\big(u_{p-1}, u_p\big)$ then by the given condition

$$\tau_{p+1} = \rho_1\big(u_p, u_{p+1}\big)$$

$$= \rho_1\big(Fu_{p-1}, Fu_p\big)$$

$$\leq [\phi\big(u_{p-1} - \phi(Fu_{p-1})] \cdot \frac{[1 + \rho_2(u_{p-1}, Fu_{p-1})] \cdot \rho_2\big(u_p, Fu_p\big)}{1 + \rho_2\big(u_{p-1}, u_p\big)}$$

$$\leq [\phi(u_{p-1}) - \phi(u_p)] \cdot \frac{[1 + \rho_2(u_{p-1}, u_p)] \cdot \rho_2(u_p, u_{p+1})}{1 + \rho_2(u_{p-1}, u_p)}$$

$$\leq [\phi(u_{p-1}) - \phi(u_p)] \cdot \rho_2(u_p, u_{p+1})$$

It follows

$$\frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_p, u_{p+1})} \leq \phi(u_{p-1}) - \phi(u_p)$$

$$0 < \frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_p, u_{p+1})} \leq \phi(u_{p-1}) - \phi(u_p)$$

$$0 < \phi(u_{p-1}) - \phi(u_p)$$

$$\phi(u_{p-1}) > \phi(u_p)$$

We conclude that the sequence $\{\phi(u_p)\}$ is not only strictly decreasing but also necessarily positive. So $\{\phi(u_p)\}$ converges to some limit $l \geq 0$.

Now for each $p \in \mathbb{N}$ we have

$$\sum_{i=1}^{p} \frac{\rho_1(u_i, u_{i+1})}{\rho_2(u_i, u_{i+1})} \leq \sum_{i=1}^{p} [\phi(u_{i-1}) - \phi(u_i)]$$

$$\leq [\phi(u_0) - \phi(u_1)] + [\phi(u_1) - \phi(u_2)] + \cdots + [\phi(u_{p-1}) - \phi(u_p)]$$

$$\leq \phi(u_0) - \phi(u_1) + \phi(u_1) - \phi(u_2) + \phi(u_2) + \cdots - \phi(u_{p-1}) + \phi(u_{p-1}) - \phi(u_p)$$

$$\leq \phi(u_0) - \phi(u_p)$$

If $p \to \infty$ then $\phi(u_p) \to l$

$$\sum_{i=1}^{p} \frac{\rho_1(u_i, u_{i+1})}{\rho_2(u_i, u_{i+1})} \leq \phi(u_0) - l < \infty$$

In other words, we can say $\sum_{i=1}^{\infty} \frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_p, u_{p+1})}$ is a finite positive number.

By induction, $\frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_p, u_{p+1})}$ is bounded in $(0, 1)$, then there exists some $\mu \in (0, 1)$ we have

$$\frac{\rho_1(u_p, u_{p+1})}{\rho_2(u_p, u_{p+1})} \leq \mu$$

$$\rho_1(u_p, u_{p+1}) \leq \mu \cdot \rho_2(u_p, u_{p+1})$$

$$\leq \mu^2 \cdot \rho_2(u_{p-1}, u_p)$$

$$\leq \mu^3 \cdot \rho_2(u_{p-2}, u_{p-1})$$

$$\dots \dots \dots$$

$$\dots \dots \dots$$

$$\dots \dots \dots$$

$$\leq \mu^{p+1} \cdot \rho_2(u_0, u_1)$$

Now, for each $p, q \in \mathbb{N}$ with $p < q$ such that

$$\rho_1(u_p, u_q) \leq [\phi(u_p) - \phi(Fu_p)] \cdot \frac{[1 + \rho_2(u_p, Fu_q)] \cdot \rho_2(u_p, Fu_q)}{1 + \rho_2(u_p, u_q)}$$

$$\leq [\phi(u_p) - \phi(u_{p+1})] \cdot \frac{[1 + \rho_2(u_p, u_{q+1})] \cdot \rho_2(u_p, u_{q+1})}{1 + \rho_2(u_p, u_q)}$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu \cdot \rho_2(u_p, u_{q+1})$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu^2 \cdot \rho_2(u_{p-1}, u_q)$$

$$\dots \dots \dots$$

$$\dots \dots \dots$$

$$\dots \dots \dots$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu^p \cdot \rho_2(u_1, u_{q-p+2})$$

$$\leq [\phi(u_p) - \phi(u_{p+1})]\mu^{p+1} \cdot \rho_2(u_0, u_{q-p+1})$$

Since, $\phi(u_p)$ is strictly decreasing, then $[\phi(u_p) - \phi(u_{p+1})]$ is very small and $\mu \in (0, 1)$ then we can conclude that $[\phi(u_p) - \phi(u_{p+1})]\mu^{p+1} < \epsilon$ then

$$\rho_1(u_p, u_q) < \epsilon \cdot \rho_2(u_0, u_{q-p+1})$$

$$< \epsilon$$

This implies that $\{u_p\}$ is the Cauchy sequence.

Since S is complete. By the continuity of $: (S, \rho_1) \to (S, \rho_1)$, for any $u_0 \in S$

$$u_0 = \lim_{p \to \infty}[F^p(u_0)]$$

$$= \lim_{p \to \infty}[F . F^{p-1}(u_0)]$$

$$= F\left(\lim_{p \to \infty}[F^{p-1}(u_0)]\right)$$

$$= F(u_0)$$

Thus, $u_0 \in S$ is a fixed point of F.

Suppose $v_0 \in S$ is another fixed point of F, then

$$\rho_2(u_0, v_0) = \rho(Fu_0, Fv_0)$$

$$\leq u \cdot \rho_2(u_0, v_0)$$

$$(1 - \mu) \cdot \rho_2(u_0, v_0) \leq 0$$

$$\rho_2(u_0, v_0) = 0$$

$$u_0 = v_0$$

Hence, u_0 is a unique fixed point of F.

Similarly, by applying some more conditions to the above result, we make a new result.

Theorem 4. Let S be a non-empty set. Suppose ρ_1 and ρ_2 be two metrics on S and $F, F_p : S \to S$ be the functions. If for all $u, v \in S$ such that

(a) $(S, \rho_1), (S, \rho_2)$ and F satisfy the hypothesis of Theorem 3
(b)   The sequence F_p uniformly converges on (S, ρ_1) to F
(c) $\exists \ \lambda > 0$ we have $\rho_2(Fu, Fv) \leq \lambda \cdot \rho_1(u, v)$

Then for every $u_p \in S$, sequence $\{u_p\}$ converges to a unique fixed point u_0 of F.

Proof. We prove that every sequence $\{u_p\} \subseteq S$ converges to a unique fixed point $u_0 \in S$. Since for some $p \in \mathbb{N}$

$$F^p(u_p) = u_p$$

Now,

$$\rho_1(u_p, u_0) = \rho_1\left(F_p^2(u_p), F^2(u_0)\right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + \rho_1 \left(F^2(u_p), F^2(u_0) \right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(u_{p+1})] \cdot \rho_2 \left(F^2(u_p), F^2(u_0) \right)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(u_{p+1})]\mu \cdot \rho_2(Fu_p, Fu_0)$$

$$\leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + [\phi(u_p) - \phi(u_{p+1})]\mu\lambda \cdot \rho_1(u_p, u_0)$$

Since $\phi(u_p)$ is strictly decreasing then $[\phi(u_p) - \phi(u_{p+1})]$ is very small and $\mu \in (0, 1)$ then we conclude that $[\phi(u_p) - \phi(u_{p+1})]\mu\lambda < \epsilon$ then

$$\rho_1(u_p, u_0) \leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right) + \epsilon \cdot \rho_1(u_p, u_0)$$

$$(1 - \epsilon) \cdot \rho_1(u_p, u_0) \leq \rho_1 \left(F_p^2(u_p), F^2(u_p) \right)$$

$$\rho_1(u_p, u_0) \leq (1 - \epsilon)^{-1} \cdot \rho_1 \left(F_p^2(u_p), F^2(u_p) \right)$$

$$\leq (1 - \epsilon)^{-1} \cdot \left[\rho_1 \left(F_p^2(u_p), F \cdot F_p(u_p) \right) + \rho_1 \left(F \cdot F_p(u_p), F^2(u_p) \right) \right]$$

$$\leq (1 - \epsilon)^{-1} \cdot \left[\rho_1 \left(F_p^2(u_p), F \cdot F_p(u_p) \right) + \epsilon_1 \cdot \rho_1 \left(F_p(u_p), F(u_p) \right) \right]$$

It is given that F_p uniformly converges to F in metric ρ_1, then $\rho_1 \left(F_p^2(u_p), F \cdot F_p(u_p) \right) \to 0$ and $\rho_1 \left(F_p(u_p), F(u_p) \right) \to 0$ as $p \to \infty$. This implies that

$$\rho_1(u_p, u_0) \leq (1 - \epsilon)^{-1} \cdot \left[\rho_1 \left(F_p^2(u_p), F \cdot F_p(u_p) \right) + \epsilon_1 \cdot \rho_1 \left(F_p(u_p), F(u_p) \right) \right] \to 0$$

It means

$$\rho_1(u_p, u_0) \to 0$$

as $p \to \infty$.

Hence, $\{u_p\}$ converges in (S, ρ_1) to a unique fixed point u_0 of F.

By the above theorems, we proved the new fixed point results on a set with two metrics using the idea of a bilateral contraction. Now, we will take an example, which helps us to prove the inequalities, which we used in the above results and disprove the other contraction inequalities.

Example 1. Let $S = \{0, 1, 2\}$ endowed with the metric ρ_1 and ρ_2 defined for all $u, v \in S$

$$\rho_1(u, v) = \begin{cases} 0 & if \quad u = v \\ 1 & if \quad u \neq v \end{cases} \qquad and \qquad \rho_2(u, v) = |u - v|$$

Let $F : S \to S$ defined by

$$F(0) = 0, F(1) = 2 \ and \ F(2) = 0$$

Define $\phi : S \to [0, \infty)$ as

$$\phi(0) = 0, \phi(1) = 4 \ and \ \phi(2) = 2$$

Prove that for all $, v \in S$, F satisfies

$$\rho_1(Fu, Fv) \leq [\phi(u) - \phi(Fu)] \cdot \rho_2(u, v)$$

We prove for all $u, v \in S$

(i) For $(u, v) = (0, 0)$:

$$\rho_1(F0, F0) \leq [\phi(0) - \phi(F0)] \cdot \rho_2(0, 0)$$

$$\rho_1(0, 0) \leq [\phi(0) - \phi1(0)] \cdot \rho_2(0, 0)$$

$$0 \leq [4 - 2] \cdot |1 - 0|$$
$$1 \leq 2$$

(iii) For $(u, v) = (1, 1)$:

$$\rho_1(F1, F1) \leq [\phi(1) - \phi(F1)] \cdot \rho_2(1, 1)$$
$$\rho_1(2, 2) \leq [\phi(1) - \phi(2)] \cdot \rho_2(1, 1)$$
$$0 \leq [4 - 2] \cdot |1 - 1|$$
$$0 \leq 0$$

(iv) For $(u, v) = (1, 2)$:

$$\rho_1(F1, F2) \leq [\phi(1) - \phi(F1)] \cdot \rho_2(1, 2)$$
$$\rho_1(2, 0) \leq [\phi(1) - \phi(2)] \cdot \rho_2(1, 2)$$
$$1 \leq [4 - 2] \cdot |1 - 2|$$
$$1 \leq 2$$

(v) For $(u, v) = (2, 0)$:

$$\rho_1(F2, F0) \leq [\phi(2) - \phi(F2)] \cdot \rho_2(2, 0)$$
$$\rho_1(0, 0) \leq [\phi(2) - \phi(0)] \cdot \rho_2(2, 0)$$
$$0 \leq [2 - 0] \cdot |2 - 0|$$
$$0 \leq 4$$

(vi) For $(u, v) = (2, 2)$:

$$\rho_1(F2, F2) \leq [\phi(2) - \phi(F2)] \cdot \rho_2(2, 2)$$
$$\rho_1(0, 0) \leq [\phi(2) - \phi(0)] \cdot \rho_2(2, 2)$$
$$0 \leq [2 - 0] \cdot |2 - 2|$$
$$0 \leq 0$$

Hence, for all , $v \in S$, F satisfied the given inequality.

Now, we check F doesn't satisfy other contraction inequalities. Suppose the contraction inequality on two metrics:

$$\rho_1(Fu, Fv) \leq \lambda \cdot \rho_2(u, v)$$

for some $\lambda > 0$.

For $(u, v) = (1, 2)$:

$$\rho_1(F1, F2) \leq \lambda \cdot \rho_2(1, 2)$$
$$1 \leq \lambda \cdot |1 - 2|$$
$$1 \leq \lambda \cdot |-1|$$
$$1 \leq \lambda$$

This is false for $0 < \lambda < 1$. So

$$1 \nleq \lambda$$

Hence, F doesn't satisfy $\rho_1(Fu, Fv) \leq \lambda \cdot \rho_2(u, v)$.

REFERENCES

[1] Almezel, S., Ansari, Q. H., & Khamsi, M. A. (Eds.). (2014). Topics in fixed point theory (Vol. 5). Cham: Springer.

[2] Alqahtani, O., & Karapınar, E. (2019). A bilateral contraction via simulation function. Filomat, 33(15), 4837-4843.

[3] Chávez, E., Navarro, G., Baeza-Yates, R., & Marroquín, J. L. (2001). Searching in metric spaces. ACM computing surveys (CSUR), 33(3), 273-321.

[4] Chen, C. M., Joonaghany, G. H., Karapınar, E., & Khojasteh, F. (2019). On bilateral contractions. Mathematics, 7(6), 538.

[5] Hjaltason, G. R., & Samet, H. (2003). Properties of embedding methods for similarity searching in metric

spaces. IEEE Transactions on Pattern Analysis and machine intelligence, 25(5), 530-549.

[6] Huang, L. G., & Zhang, X. (2007). Cone metric spaces and fixed point theorems of contractive mappings. Journal of mathematical Analysis and Applications, 332(2), 1468-1476.

[7] Iseki, K. (1975). A common fixed point theorem. Rendiconti del Seminario Matematico della Università di Padova, 53, 13-14.

[8] Kaneko, H., & Sessa, S. (1989). Fixed point theorems for compatible multi-valued and single-valued mappings. International Journal of Mathematics and Mathematical Sciences, 12(2), 257-262.

[9] Kreyszig, E. (1978). Introductory functional analysis with applications. John Wiley & Sons Canada.

[10] Maia, M. G. (1968). Un'osservazione sulle contrazioni metriche. Rendiconti del Seminario Matematico della Universita di Padova, 40, 139-143.

[11] MURESan, A. S. (2007). From Maia fixed point theorem to the fixed point theory in a set with two metrics. Carpathian Journal of Mathematics, 133-140.

[12] Rus, I. A. (1977). On a fixed point theorem in a set with two metrics. Mathematica-Revue d'analyse numérique et de théorie de l'approximation. L'analyse numérique et la théorie de l'approximation, 6(2), 197-201.

[13] Shimizu, T., & Takahashi, W. (1996). Fixed points of multivalued mappings in certain convex metric spaces. Topological Methods in Nonlinear Analysis, 8(1), 197-203.

[14] Sigh, S. P., & Pant, R. P. (1981). A common fixed point theorem in a metric space with two metrics. Pure appl. Math. Sci, 14(1-2), 35-37.

[15] Stinson, C. P., Almuthaybiri, S. S., & Tisdell, C. C. (2019). A note regarding extensions of fixed point theorems involving two metrics via an analysis of iterated functions. ANZIAM Journal, 61, C15-C30.

[16] Zezula, P., Amato, G., Dohnal, V., & Batko, M. (2006). Similarity search: the metric space approach (Vol. 32). Springer Science & Business Media.

Balancing Safety, Financial Performance, and Environmental Sustainability in Ghana's Gold Mining Operations

Lokko George William, Li Yang, Nguembi Ines Pamela, Abangbila Linda

School of Economics and Management, Anhui University of Science and Technology, Huainan, China

Abstract— Gold mining that is rapidly expanding and has become an important means of revenue for an immense number of residents in geographic areas within which it is conducted. Nevertheless, despite this acknowledged possibility, gold extraction poses a variety of difficulties for those involved, with miner safety and health being particularly risky. Our study's objective is to investigate the balance between financial performance and safety in environmental sustainability in Ghana's gold mining sector. By doing a case study, we use regression and descriptive statistics to examine the relationships between the variables to determine the tactics employed to strike a balance between safety, financial success, and environmental sustainability. These findings show that violations of occupational safety and health do occur in the gold mining sector in the research area. Consequently, the investigation recommends striking a balance between protection, monetary success, and sustainable development. A greater prevalence of protective clothing as well as routine incorporation of aerial photography into governmental evaluations of gold extraction operations are all attainable objectives for achieving requirements for workplace health and safety, boosting Ghana's economic output, and ensuring the longevity of the environment. we conclude that the findings of our study as gold mining industry in Ghana, which is rapidly expanding and widely practiced throughout Sub-Saharan Africa, is an important source of earnings for a large number of people in the regions where it is conducted. Nevertheless, regardless this acknowledged prospective, the extraction of gold presents a number of challenges to the individuals whose partake in it, with the well-being and security of laborers being especially important. The implementation of the latest cutting-edge approach should be made a policy they are as follows. The greatest environmental dangers are associated with conventional mining methods like open pit and underground mining. These practices should be banned and enforced. Mining waste reuse. Setting up other industries for the use of mining waste. This can help recycle mining waste and help make the environment safe and friendly

I. INTRODUCTION

1.1 BACKGROUND

Every nation's objective is to construct a robust economy that experiences swift job creation and advancement. In fact, entities were actually classified according to their degree of prosperity. Nations with the greatest development are

known to have mature finances, while those with the lowest levels of development are known as economies in flux. There are numerous economic achievement benchmarks employed for assessing how well a country is performing economically. Rising Prices, mortgage rates, general consumer demand, index of shares, the nation's economic output (GDP), currency conversion rate, and joblessness are examples of such variables. Nations with prosperous economies typically strive for macroeconomic ratings that are reliable and lasting. Inconsistency in these characteristics, on the other hand, may indicate financial issues that must be rectified for optimum prosperity.

The mining industry has long been a substantial contributor to the growth of jobs, tax revenue, and export earnings in Ghana. For decision-makers, stakeholders, and researchers, it is essential to comprehend the complex effects that mining has had on the Ghanaian economy. With regard to the Ghanaian economy's development, employment, tax income, environmental sustainability, and social results, this in-depth research tries to analyze and assess the effects of mining on each of these factors.

The effects of Ghana's mining industry on the nation's economy are still up for question, even though it has grown greatly over time. In order to inform policy decisions and encourage sustainable development in the industry, the consequences of mining on economic growth, employment, tax revenue, environmental sustainability, and social outcomes must be thoroughly analyzed and understood. The purpose of this paper is to present a thorough examination of the economic impact of mining in Ghana from 1992 to 2020. The study aims to encourage evidence-based decision-making and contribute to a better knowledge of how the industry operates by looking at a variety of aspects, including economic growth, employment, government income, environmental sustainability, and social repercussions.

1.2 Growth Of Mining In Ghana

The development of the country's economy has been considerably aided by Ghana's mining sector. The pre-colonial age, when this region had a long and rich history, saw a substantial amount of wealth coming from gold mining. Bauxite, manganese, diamonds, and most recently, oil and gas, were among the various minerals that were added to the industry over time. The most renowned of Ghana's several irreplaceable mineral resources are gold. The nation, which is the largest producer of gold in Africa, is among the top 10 producers of the metal globally. The growth of Ghana's economy, gains in foreign exchange, and export income have all been significantly influenced by the gold mining industry.

The mining sector in Ghana is governed by a legislative system that defines rules for mining operations. Mining operations are governed under the Minerals and Mining Act, 2006 (Act 703) and its further revisions. The Ministry of Lands and Natural Resources, which is also in charge of regulating the business, is responsible for developing the regulations that will ensure its long-term viability. The primary regulatory authority, the Minerals Commission, issues licenses and keeps an eye on compliance with mining laws.

The Ghanaian government has recently paid increasing attention to the need for moral and environmentally friendly mining practices. Initiatives have been taken within the mining sector to enhance CSR, community development, and environmental protection. This includes efforts to guarantee the equitable distribution of mining profits, decrease the negative environmental effects of mining operations, and promote favorable social results for individuals residing nearby. Reading the overview will enable readers to get a context-specific understanding of the historical evolution, legal system, and economic significance of the mining industry in Ghana. The review's subsequent sections can analyze how mining has affected various facets of the Ghanaian economy using this information.

Gold: Since gold has been mined in Ghana for a very long time, it continues to be a significant location for mineral wealth. After South Africa, Ghana is the continent's second-largest producer of gold. The country's exports and foreign exchange earnings are greatly boosted by the export of gold. Through taxes, royalties, and earnings, it offers a sizable source of employment to the government and financial assistance.

1.3 Objective of the Study:

The following are the specific goals that underpin the review:

1. To evaluate the mining industry's contribution to Ghana's economic expansion
2. To assess the contribution that mining has made to Ghana's fiscal management and government revenue.
3. To how much are locals in Ghana cognizant that gold extraction projects are altering the landscape?

1.4 Motivation and Contribution to the Study

The motivation and contribution to the study are essential aspects of any research, and in this case, they play a crucial role in understanding why this study on safety, financial performance, and balancing safety and environmental sustainability in Ghana's gold mining sector is important. the motivation for this study stems from the need to address critical issues in Ghana's gold mining sector, and its

financial contributions including generating data and insights that inform decision-making, promote safety, and enhance the overall understanding of the industry's impact.

II.   LITERATURE REVIEW

2.0 Important Theories or Concepts

Comprehension how mining resource theory will impact society requires a comprehension of the following key theories and ideas:

According to the cursed resource theory (Auty, 1993; Sachs & Warner, 1997), cultures with easy access to plentiful natural resources such as food usually experience poor economic and social outcomes. An over reliance on mining resources can stifle economic progress, lead to administrative problems, and be bad for the environment, claims the theory (Ross, 1999). The application of the resource curse hypothesis to the Ghanaian extractive industry allows for the analysis of potential hazards and the creation of mitigating strategies. The principles of sustainable development hold that social progress, environmental preservation, and equitable economic growth are all crucial (World Commission on Environment and Development, 1987). It understands that extraction must be done in a way that safeguards the environment and fosters fair relationships while also ensuring future financial rewards (Aryee, 2001). Viewing the effect of extraction on the Ghanaian economy through the lens of environmentally friendly development enables the recognition of policies and procedures that aim to optimize favorable effects and prevent negative impacts (Hilson&Murck, 2000). Examining the social impact, the anticipated societal repercussions of growth initiatives like extractive industries are examined using a method known as social impact assessment (SIA) (IAIA, 2018). It is necessary to assess how extractive industries affect participants, community members, and those with special needs psychologically (Vanclay, 2003). Running a SIA enables in-depth analysis of the effects of extraction on society and supports the creation of mitigation and enhancement plans for beneficial social outcomes (Kunadu&Blocher, 2012). Corporate social responsibility (CSR) includes the following: Mining firms' voluntary efforts to interact with the community and address social and ecological issues are included in business social responsibility (BSR) efforts (Van Marrewijk, 2003). The mineral extraction sector participates in corporate social responsibility (CSR) initiatives such neighborhood revitalization initiatives, ecological preservation programs, and public awareness campaigns that promote accountability and transparency (Ofori& Hinson, 2014). It is easier to assess the performance of such activities in

promoting environmentally friendly growth and addressing social issues when one is aware of the significance of CSR in the Ghanaian mining sector (Hilson&Yakovleva, 2007). We have a solid foundation for understanding how mining has impacted Ghana's economy thanks to these fundamental ideas and beliefs. While the concept of equitable growth concentrates on obtaining financial success while taking social and environmental variables into account, the "curse of resources" hypothesis places a particular emphasis on the dangers of drug consumption. Companies' social responsibility plays a crucial role in promoting environmentally responsible mining practices, and the assessment of social impact helps pinpoint and address the social effects of mining. Administrators, individuals involved, and mining entrepreneurs will be better able to manage Ghana's natural resources while advancing toward attaining equitable and sustainable growth by embracing the principles and ideas.

2.1 Mining's Economic Impact

2.1.1 GDP and Foreign Exchange Earnings Contributions

The mining sector has had a big impact on Ghana's economic development. Due in large part to gains in foreign exchange, investments, and ties to other economic sectors, the sector has significantly raised the country's GDP. Mining activity money has been crucial in fostering infrastructure growth and social service investment, both of which are essential for the advancement of the economy and the well-being of society. In addition to other developmental activities, these expenditures have aided in the development of public utilities, education and healthcare facilities, and transportation networks (World Bank, 2020; Aryee, 2016). Additionally, Ghana's industrialization and economic diversification have been sparked by the mining industry. The existence of the business has encouraged the expansion of related industries including manufacturing, construction, and transportation. The interconnection of the mining industry with other industries has increased employment possibilities and fueled global economic growth (Aryee, 2016). Ghana's economic expansion has also been aided by foreign exchange revenues from exports of mining products. Improvements are made to the country's standing in international trade, the state of its balance of payments, and the availability of resources for the importation of products and services supporting various economic activities (World Bank, 2020). Ghana's economy has benefited from the mining sector's backing of technological development and innovation. Modern tools, equipment, and knowledge are often needed for mining activities, which promotes the development and application of cutting-edge technologies. This technological transfer and its knock-on effects have the

potential to increase overall productivity and competitiveness across all economic sectors (Aryee, 2016). It is crucial to keep in mind that the level of economic growth that mining contributes to might vary depending on a range of variables, such as commodity prices, governmental regulations, and environmental sustainability. To provide long-term advantages for Ghana's economy and its people, mining requires careful management, strong legislation, and ethical standards.

2.1.2 Creation of Jobs

Ghana's economy has benefited from the mining sector's backing of technological development and innovation. Modern tools, equipment, and knowledge are often needed for mining activities, which encourages the employment of cutting-edge technologies. Other industries' overall productivity and competitiveness may increase because of technology transfer and information leaks (Aryee, 2016). It is crucial to remember that the level of economic growth that mining promotes might change depending on a range of variables, such as commodity prices, governmental constraints, and the sustainability of the environment. To have a long-term good economic influence on Ghana's economy and population, mining must be rigorously managed and supervised by strict legislation and moral principles. The demand for goods and services in mining towns is rising, which has resulted in local businesses expanding and new employment being created (Ghana Chamber of Mines, 2020). The supply chain's need for the products and services provided by the mining industry leads to indirect employment. For instance, the transfer of employees, supplies, and equipment to and from mining locations requires transportation services. Building infrastructure to support mining operations is a normal task for construction businesses. The production of the equipment, supplies, and other inputs required by the mining industry benefits the manufacturing sector. These opportunities for indirect employment contribute to the growth of jobs across the economy's many sectors (World Bank, 2020). Mining has many advantages for employment, especially in mining districts, which have significantly improved livelihoods and decreased poverty. People have been able to satisfy their basic needs, have access to necessary services, and improve their living conditions because of the employment possibilities in the sector and the consistent income they have offered. As a result, these communities now enjoy higher living conditions and have lower rates of poverty (Ghana Chamber of Mines, 2020). It is crucial to stress that more funding, skill development, and regional economic diversification are necessary for the mining sector to sustainably generate jobs. Enhancing the connections between the mining industry and other sectors

will help to encourage the growth of other industries outside of mining. By using this strategy, a wider spectrum of people and communities may benefit from an economy that is more resilient and inclusive.

2.1.3 Fiscal Management and Government Revenue

Mining has been a major source of revenue for the Ghanaian government, which has relied on it to support the nation's economy and fund other initiatives. Businesses operating in the mining sector contribute to the government in several ways, including taxes, royalties, and dividends. Corporate income tax, withholding tax, and value-added tax (VAT) are taxes that miners are subject to. These taxes provide a large chunk of revenue for the government, which is used to pay for all its expenditures. Royalties, which are typically determined as a percentage of the value of the generated minerals, provide additional funding to the government (Ghana Extractive Industries Transparency Initiative, 2021). Across the nation, infrastructure development projects have been sponsored in large part thanks to the money generated by mining operations. Mining profits have helped investments in telecommunications infrastructure, energy systems, transportation networks, and water supply. Higher connection, higher economic activity, and general improvements in living conditions that support both mining activities and the general populace are all advantages of these infrastructure investments (World Bank, 2020). Additionally, mining has contributed money to initiatives aimed at enhancing social welfare, education, and healthcare. Investments in these industries support inclusive growth and the lowering of socioeconomic inequality. For instance, mining profits have been used to fund social assistance programs and scholarships for disadvantaged communities, as well as to construct schools, hospitals, and other healthcare facilities (Initiative for Transparency in Ghana's Extractive Industries, 2021). However, maintaining efficient financial management and equitable sharing of mining profits remains challenging. Mechanisms that are transparent and accountable are needed to monitor the allocation and collection of mining earnings. Governance frameworks need to be enhanced, revenue management systems need to be improved, and fiscal responsibility must be promoted for mining money to be used essentially in the interests of the entire populace (World Bank, 2020). Addressing the problem of money leakage and ensuring that mining operations are done morally and legally are also essential. The development of the equitable distribution of mining profits as well as the halting of illegal financial transfers can both benefit from increased accountability and transparency in the sector (Ghana Extractive Industries Transparency Initiative, 2021). In conclusion, mining operations have greatly increased the revenue received by

the Ghanaian government, helping to fund budgets, the construction of infrastructure, and social initiatives

Furthermore, a great deal of research has demonstrated that the health of mining communities is negatively impacted by both large- and small-scale gold mining. Health issues in mining communities have gotten worse because of Chinese miners' recent involvement in gold mining. Most underprivileged people in mining towns who have little other options for making a living turn to illegal gold mining, where they endure dangerous working conditions that can occasionally result in injury or death. This section looks at how Ghanaians are affected by China's large-scale, regional, and small-scale mining operations in terms of their health.

2.6 Impacts of Large-Scale Gold Mining on Health

Ghana uses the substantial revenue it receives from its extensive gold mining industry to fund its growth. It is not viable for the nation to efficiently pursue development objectives without a sizable gold mining sector. Nonetheless, there is an uneven distribution of the money generated in this industry. The citizens of mining villages bear the brunt of the harm inflicted by mining companies, which exacerbates the problem even further. Research indicates that large-scale gold mining is a hazardous industry linked to hygienic problems, pollution, and bad health. The effect of extensive gold mining on the well-being of mining communities.

2.6.1 Hygiene and pollution

Bempah and Ewusi (2016) assessed the danger to human health posed by heavy metal contamination in the Obuasi gold mining area and found that most wells had levels of arsenic, mercury, iron, manganese, chromium, and cadmium that were higher than WHO drinking water quality criteria. Furthermore, their investigation revealed that the levels of arsenic and nickel in vegetables from three communities in the study area Sanso, Dokiivaa, and Pamporawere higher than those allowed by WHO guidelines. Furthermore, the highest rate of bioaccumulation was found in oxygen veggies, which were followed by Pampora and Tokiiwa vegetables. As a result, soil pollution from heavy metals and other pollutants is increased in plants growing in oxygen. The carcinogenic risk of arsenic from eating vegetables and drinking well water was outside the permissible risk level, which meant that residents of the three towns had a higher chance of developing cancer. Furthermore, because they have higher risk index values (the rate of potential exposure to toxins at levels where no harmful effects are expected) for arsenic, lead, and mercury, people of mining districts may experience additional health issues from vegetable eating. vegetable.

Usman et al. (2021) focus on Royal Adamus Ltd.'s mining activities based on field research. All around their location, several dips and holes were created. The neighborhood members are at danger for various health issues due to the stagnant water in these pits and ditches. Initially, it provides a home for dangerous reptiles like snakes, endangering the life of the occupants. Additionally, it may turn into a mosquito breeding site, which could result in an increase in malaria cases. Communities around mining regions are exposed to contaminants such smoke, dust, and chemicals, as noted by Usman et al. (2021). Some Nkroful locals protested in 2018 against the mining firms' usage of dirt roads, which was causing severe air pollution. The protests coincide with a rise in respiratory illnesses among the populace because of extreme air pollution.

The amounts of heavy metals and metalloids in drinking water from wells in eighteen Tarkwa settlements were determined by Borti-Sam et al. (2015), along with any possible health hazards. Study 51 evaluated the health concerns posed by carbon monoxide, manganese, nickel, zinc, arsenic, cadmium, chromium, copper, iron, lead, and manganese in community drinking water. In certain localities, the levels of heavy metals in well-sourced drinking water surpass the WHO guidelines for safe drinking water. The risk index (non-carcinogenic health risk) for children in the Juniso neighborhood (1.08) was greater than the adult risk (0.781) in accordance with U.S. Environmental Protection Agency (USEPA) criteria. In neighborhoods like Samahu and Mile 7, drinking well-water contaminated with arsenic increased the risk of cancer in both adults and children. The average cancer risk from consuming well water near the Tarkwa gold mine included 3.65E-05 arsenic, according to USEPA rules. Adults 5.08E-05; children 5.08E-05. Consequently, for every 100,000 people, there are 3 cases of neoplasms in adults and 5 cases in children.

However, Faanu et al. (2011) discovered that there is no radiation risk to the populations surrounding Tarkwa from gold mining operations. The study considered the four ways that the general populace in the mining area could be exposed to radiation: inhaling radon gas, breathing dust containing uranium-238 and thorium-232, drinking water containing natural radioactivity, and being exposed to gamma rays from soil and rocks. Regarding all exposure routes combined, the mean yearly radiation dosage was 0.69mSv. The amount is less than the International Commission on Radiological Protection's (1mSv/year) authorized exposure level. Even though radon gas was responsible for 42% of the average yearly radiation dose across all exposure routes, the dose was still below the ICPR's threshold, negating the need for corrective action. However, Faanu et al. (2011) suggested that local mining businesses set up monitoring programs to manage radon gas.

This is since growing radon gas exposure is strongly linked to the development of cancer (Robertson et al., 2013). Furthermore, the gas is more harmful because it is invisible (ibid.). The results of the studies conducted by Faanu et al. (2011) and (2016) are similar. According to Faanu et al.'s (2016) 52 findings, there are no radiological health risks to the nearby communities because of gold mining at Newmont Golden Ridge Ltd. (Akyem).

III.   METHODOLOGY

Deductive and inductive components are combined in the research methodology. In deductive studies, the investigation is guided by the current theory and presumptions. The gathered data is then used to support or challenge the hypothesis, assisting in its revision. The present section illustrates the process used to carry out this investigation, which is divided into the following sections: research strategy; research strategy; data suppliers; data analysis; measuring variables; and estimating method. The inductive strategy starts by examining the reason for the study (a commercial issue, a company, a financial problem, and so on) and then tries to develop outcomes theories from the study's findings via examination using various research methodologies (Greener, 2008). The last stage of the inductive hypothesis technique is for the examiner to collect further data to assess if the hypothesis will be valid or otherwise (Bryman and Bell, the year 2011).

3.1 Research Approach

For this study, relevant works that had been published in scholarly journals, books, reports, and other trustworthy sources were found and evaluated using a thorough literature review approach. The review adopted a planned, systematic methodology to guarantee the inclusion of all pertinent, thorough, and varied literature. This empirical study aims to test the hypotheses presented in section 2.6 using a strong statistical methodology. To that end, the output method for GDP analysis has been selected because it provides information into the role of all industries as well as the capacity to identify the potential influence of the gold mining industry. After gathering information and administration, the study began by generating descriptive data and analyzing possible difficulties with multicollinearity, heterogeneity, and oscillation. The suitableness of using random vs fixed impacts was subsequently assessed. After running all of these statistical evaluations, as can be seen below, we succeeded to establish an appropriate estimating strategy for testing the hypotheses given in the present investigation.

3.1.1 Mathematical formulas

 Our research work base on theoretical and empirical study.

In our study we employed a statistical approach for sampling all 510 survey respondents. By doing a case study, we use regression and descriptive statistics to examine the relationships between the variables to determine the tactics employed to strike a balance between security, financial success, and environmental sustainability.

The data set sizes were calculated using the Cochran (Cochran, 1963) calculation. This was used due to the unclear population.

$$n_0 = \frac{Z^2 pq}{e^2}$$

n_n =Size of the sample,
- Z^2 = the desired confidence level is abscissa of the normal curve that cuts off an area at the tails $1 - \alpha$, l, e.g., 95%,
- e is the desired degree of accuracy.
- p is the estimated percentage of an attribute that the population possesses.
  - q is $1 - p$.

Where;

- $Z\ score\ =\ 1.05$
- $p\ =\ 0.5$
- $q\ =\ 1 - p$
- $e\ =\ 0.05$

Therefore.

$$n_0 = \frac{Z^2 pq}{e^2}$$

$$n_0 = \frac{(2.05)^2 (0.5)(0.5)}{(0.05)^2} = 510$$

The linear regression equation is:

$$y = \beta_0 + \beta_1 x + \varepsilon$$

 Whereas.

Y represents what can be expected from the subject variable (y) considering any factor in the independent variable (x).

β_0 is the intercept, or the value of y that is anticipated when x is 0.

β_1 regression coefficient

X is the independent variable (the one that we anticipate impacting y). ε is our estimate of the logistic statistic's estimation error, or how much it differs from our estimate?. With looking for the correlation parameter (β_1) which optimizes the prediction's aggregate error (ε) (Zou et al., 2003), linear regression discovers the best-fitting line through the data. Using this technique, each hypothesis was evaluated. The relationship between the uncorrelated variables as well as dependent factors was analyzed using

logistic regression as well as correlation techniques. The adoption of OSH practices by smallholder coal miners was the dependent variable (y) in this section, and the independent variables (X) were sociocultural characteristics, common OSH concerns, managerial commitment, training, and demographic characteristics.

After gathering information and administration, the study began by generating descriptive data and analyzing possible difficulties with multicollinearity, heterogeneity, and oscillation. The suitableness of using random vs fixed impacts was subsequently assessed.

In order check the multicollinearity we use VIF, which is called variance inflation factor, the mathematical for calculating VIF manually is;

$$VIF_i = \frac{1}{1 - R_j}$$

Whereas, R_j is residual correlation regression.

In order to heterogeneity, we use the mathematical formula;

Mathematically, I^2 is expressed as $I^2 = \tau^2 / (\sigma^2 + \tau^2)$, where τ^2 denotes the between-trial heterogeneity, σ^2 denotes some common sampling error across trials, and $(\sigma^2 + \tau^2)$ is the total variation in the meta-analysis.

Pearsons Chi Square Test:

The Pearson chi-Square test is used to determine whether the variables are related.

$$\chi^2 = \frac{(o_i - n_{p_i})^2}{n_{p_i}}$$

Odd Ratio

The odds ratios (OR) were built in a nested model, starting with the primary predictor and compositional factors model, contextual factors model, and working circumstances model. An odds ratio (OR) of one meant that increasing the predictor's value had no bearing on the probability of developing occupational health issues; an $OR > 1$ meant that the predictor was linked to a higher probability of doing so; and an $OR < 1$ meant that the predictor variable was linked to a lower probability of doing so.

$$odds = \frac{P}{1 - P}$$

Model 1: Logistic Regression

$$\log(odds) = logit(P) = \ln\left(\frac{P}{1 - P}\right)$$

Logistic Curve

$P = \frac{e^{a+bX}}{1+e^{a+bX}}$ or $P = \frac{1}{1+e^{-(a+bX)}}$

$-2LogL$

$$\chi^2 = -2LL_R - (-2LL_F) = -2ln\left(\frac{likelihood_R}{likelihood_F}\right)$$

Model 2: Probit Regression

In probit regression, the cumulative standard normal distribution function $\Phi(.)$ is used to model the regression function when the dependent variable is binary, that is, we assume.

$$E\left(Y/X\right) = P\left(Y = \frac{1}{X}\right) = \Phi(\beta_0 + \beta_1 X).$$

Model 3: Logit Regression

The population logit regression function is;

$$P\left(Y = 1/X_1, X_2, \dots\dots, X_k\right)$$
$$= F(\beta_0 + \beta_1 X_1 + \cdots\dots\dots + \beta_k X_k)$$
$$= \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \cdots\dots + \beta_k X_k)}}$$

3.2 Online literature search and data

Using electronic databases like PubMed, Scopus, Web of Science, and Google Scholar, a thorough literature search was carried out. Variations of the words "mining," "Ghana," "economy," and similar terms were used as search criteria. The search was restricted to English-language works with a particular emphasis on works released between 1992 and 2022.

3.3 Criteria for Inclusion and Exclusion:

Based on their value and relevance to the study's objective, studies that met the inclusion and exclusion criteria were chosen for inclusion. Additionally included were peer-reviewed books, articles, papers, and studies that provide information, conceptual frameworks, or analytical viewpoints on how mining affects the Ghanaian economy the elimination of duplicate studies, useless research, and works of opinion.

IV. DISPLAY, EVALUATION, AND CONVERSATION OF RESULTS

4.1 Presentation of Findings

4.1.1 Study Area

The investigation was conducted in the southwest of Ghana. Owing to the region's wealth of mineral resources, gold mining is very desirable. Numerous artisanal mining concessions, along with some of the biggest and most well-established mining firms, are situated here.

4.2 Procedure for Data Collection and Sampling

The study's data were collected from January 2022 to December 2022. Contextual aspects, compositional features,

and working condition quality assessments were the three portions of the questionnaire that were developed and modified based on previous studies in the same field. It consisted of closed-ended questions with multiple-choice answers so that respondents may choose the right response. Fifteen volunteers completed the questionnaire to ensure its validity and feasibility. The questionnaire was modified to make it easier to comprehend after the pilot group was asked to complete it and provide input on how comprehensible it was. Random selection was used to select survey participants. Participants who had worked for less than a month or who were younger than eighteen were not recruited by us. Out of the 510 gold miners who were recruited, 504 of them consented to participate in the survey. One of the reasons they were unable to participate in the study was time constraints. The sample size was determined using a 50% estimated population proportion, a 95% confidence interval, and a 5% error rate.

4.2.1 The Derivation of the Response Variable

The health problems that Ghanaian goldminers faced as a result of their work were the study's response variable. Respondents who were asked if they had seen any symptoms of illnesses related to gold mining since they started working in the industry said that they had. "Yes" was indicated in the response if the responder checked at least one disease, and "No" if none were. One code for yes and zero for no was assigned to the binary response.

4.2.2 Crucial Predictor Elements

The main predictor of the study was created by combining the department and subsector variables. The predictor known as subsector department is composed of four mutually incompatible groupings: ASM production, ASM non-production, LSM production, and LSM non-production.

4.2.3 Compositional and Contextual Components

The sociodemographic characteristics of the gold miners were correlated with compositional indicators in this study. Among these were factors like age, sex, marital status, years of experience, and education. Years of residency, shift employment, physical examination, and proximity to mine sites were examples of contextual influences.

4.3 Working Environment

It was asked of the participants to rate their working conditions. Each of the four indicators was scored using a series of questions, and the results were as follows: very poor (1), poor (2), good (3), very good (4), and excellent (5). An overall score of three or higher was considered "good," whereas a score of one or lower was considered "poor." The functional state of the gold miners was referred to as "health" in this study. These include the rate at which physical fitness, mental stability, and health status are

changing. "Safety" encompasses the provision of appropriate personal protective equipment, such as goggles, gloves, and protective clothing, in addition to the institutionalization of protocols such as acceptable noise levels, fall protection, and the correct disposal of hazardous chemicals. Everyone knows that the word "environment" encompasses both the social and physical spheres. These include, but are not restricted to, the equipment required for the job, their thoughts on the layout and standard of their workspace, the neighborhood, and the amount of space that is available. Workload, incentives, wages or income, and job perks are further instances of "economic conditions" that jointly impact the productivity of goldminers.

The selection of these variables as significant predictors, compositional and contextual factors, and working conditions was influenced by the literature, practical significance, theoretical relevance, and parsimony.

4.4 Data Evaluations

The following analytical procedures were followed. First, descriptive analysis was used to determine the distributions and percentages of the goldminers' qualities. Next, using Pearson's chi-square statistic, the relationship between the categorical independent variables and the goldminers' experiences with health difficulties related to their line of work was analyzed and explained. A negative log-log bivariate regression was utilized to ascertain the "one-on-one" predictive relationship between the predictors and the dependent variable prior to the multivariate model being implemented. The data was subjected to multivariate statistical analysis using a nested binary logistic regression model in order to examine the relationships and proportions between factors that influence having health problems related to one's job while accounting for theoretically significant compositional, contextual, and working condition factors.

Logistic regression makes it possible to tie the model to the response variable by enabling each measurement's amount of variance to be a function of its predicted value and by assuming a binary response (Yes/No). The link function provides access to alternatives like the logit model, probit model, negative log-log, and complementary log-log models. Both logit and probit link functions share the chance that an observation in each category of a binary outcome variable (having health problems related to their job or not) has the same probability of approaching 0 as well as approaching 1 ($50\% \, No, 50\% \, Yes$). The complementary log-log or negative log-log of the link function is chosen correspondingly when there is an unequal success of probability in the observations of a binary result, that is, when there are more or fewer 0s than 1s. The statistical evidence indicates that there was an uneven probability of

the outcome, as 68.06% of the goldminers in this study did not have health difficulties related to their occupation. Thus, the negative log-log link function was used to model the dependent variable suitably.

The odds ratios (OR) were built in a nested model, starting with the primary predictor and compositional factors model, contextual factors model, and working circumstances model. Higher predictor values had no effect on the risk of having occupational health problems, according to an odds ratio (OR) of one; an OR >1 indicated a correlation between the predictor and a higher likelihood of developing occupational health problems; and an $OR < 1$ showed that there was a correlation between the predictor variable and a decreased risk of occupational health issues. All statistical analyses were performed using Stata 15 SE software, with a 95% confidence interval and a statistical significance threshold of 0.05.

4.5 Outcomes

4.5.1 Qualitative and Quantitative Findings

Table 1 displays the descriptive and inferential findings of

the investigation. The age range of the participants was 17–60. One to fifty-two years of experience were among the miners $(M = 8.0765, SD = 5.34567)$. $Notably, 55.56\%$ of ASM miners working in production departments and 75.87% of ASM miners in non-production departments reported no health problems as a result of their work across subsectors and departments. Just 14.87% of LSM miners who were not in production were impacted by occupational health issues, but 15.98% of miners who were. A study found that 57.32% of miners who reported bad health conditions at work encountered occupational health concerns, compared to just 27% of miners who reported favorable health conditions at work. Occupational health issues were reported by $39.03\%, 41.01\%, and\ 38.85\%$ of goldminers who, respectively, experienced unfavorable economic, environmental, or safety conditions. Furthermore, goldminers regarded the economic, environmental, and safety elements favorably. Of these, $26\%, 25.55\%, and\ 21.98\%$ of them, respectively, reported having health issues associated to their employment.

Table 1: shows the percentage distribution and demographic characteristics of people experiencing health issues connected to their jobs by predictor variables.

Variables	Weighed Frequency	Weighed Percentage	Experiencing occupational related health problems		Inferential statistics
			No (%)	Yes (%)	
Subsector + Department $\chi2\ (3)\ =\ 41.1453, p < 0.001$					
ASM Production	280	55.24	158 (55.09)	120 (41.71)	
ASM Non-production	20	3.26	14 (75.36)	6 (22.42)	
LSM Production	55	11.01	40 (72.01)	8 (15.88)	
LSM Non-production	154	30.85	131 (83.06)	27 (14.78)	
Age $\chi2\ (3)\ =\ 10.9976, p < 0.05$					
17–23 years	171	32.12	128(74.34)	40 (23.44)	
24–33 years	240	47.03	152 (62.53)	87 (35.25)	
34–53 years	66	12.18	39 (58.61)	26 (39.28)	
Above 54 years	27	4.45	27 (81.05)	8 (16.96)	
Gender $\chi2\ (1)\ =\ 8.1456, p < 0.05$					
Male	430	85.22	306 (69.17)	130 (28.62)	
Female	74	14.78	37 (55.31)	33 (44.62)	
Marital status $\chi2\ (1)\ =\ 9.9461, p < 0.05$					

Variables	Weighed Frequency	Weighed Percentage	Experiencing occupational related health problems		Inferential statistics
			No (%)	Yes (%)	
Single	330	67.16	240 (71.64)	89 (26.14)	
Married	174	34.62	103 (56.81)	72 (40.21)	
Education	$\chi 2\,(2)\,=\,8.4503, p < 0.05$				
No formal/Primary/Junior High	200	39.98	126 (62.75)	70 (35.05)	
Senior High	130	26.01	83 (63.21)	46 (34.77)	
Tertiary	174	34.82	135 (75.12)	45 (22.87)	
Experience	$\chi 2\,(2)\,=\,2.7601, p\,=\,0.127$				
1–4 years	290	56.23	190 (65.33)	95 (32.45)	
5–9 years	119	22.50	77 (65.21)	39 (32.88)	
Above 9 years	95	20.14	76 (74.15)	29 (23.65)	
Medical Checkup	$\chi 2\,(1)\,=\,4.8765, p < 0.05$				
No	198	37.78	120 (61.14)	70 (36.65)	
Yes	310	62.22	223 (70.64)	91 (27.14)	
Years of Residence	$\chi 2\,(1)\,=\,4.3181, p\,=\,0.119$				
1–4 years	145	27.88	95 (65.33)	48 (32.45)	
5–9 years	131	25.28	81 (61.21)	49 (36.77)	
Above 9 years	228	45.93	167 (71.46)	64 (26.32)	
Shift	$\chi 2\,(1)\,=\,1.3547, p\,=\,0.124$				
No	390	76.2	265 (65.64)	129 (32.14)	
Yes	110	20.5	78 (73.84)	32 (26.38)	
Proximity	$\chi 2\,(1)\,=\,17.6300, p < 0.001$				
No	270	52.26	208 (77.39)	65 (22.41)	
Yes	238	47.72	135 (60.47)	96 (31.43)	
Health conditions	$\chi 2\,(1)\,=\,33.7573, p < 0.001$				
Poor	94	16.55	30 (40.46)	51 (57.32)	
Good	410	81.44	313 (74.74)	110 (28.28)	
Safety conditions	$\chi 2\,(1)\,=\,10.7684, p < 0.05$				

Variables	Weighed Frequency	Weighed Percentage	Experiencing occupational related health problems		Inferential statistics
			No (%)	Yes (%)	
Poor	254	50.6	150 (60.03)	94 (37.86)	
Good	250	49.4	193 (75.81)	46 (24.78)	
Environmental conditions $\chi 2\,(1)\,=\,\mathbf{10.1754}, p < 0.05$					
Poor	214	40.45	120 (49.78)	80 (44.18)	
Good	290	55.54	223 (70.45)	81 (25.76)	
Economic conditions $\chi 2\,(1)\,=\,\mathbf{17.0045}, p < 0.001$					
Poor	272	55.67	145 (59.99)	110 (38.45)	
Good	232	45.03	178 (66.34)	55 (20.35)	

Includes a demonstration of the chi-square independence test by Pearson. Using Pearson's chi-square test, the observed differences in experiencing occupational health problems and compositional variables, together with contextual and working conditions factors, were examined for independence. The primary predictor was statistically significantly correlated with both the subsector department and the experience of occupational health concerns $(\chi 2\,(3)\,=\,41.1435, p < 0.001)$. In respect to the compositional variables, there was a statistically significant association between age $(\chi 2\,(3)\,=\,12.10078, p < 0.05)$, $gender\,(\chi 2\,(1)\,=\,6.0001, p < 0.05)$, married status $(\chi 2\,(1)\,=\,9.1067, p < 0.05)$, and education $(\chi 2\,(2)\,=\,5.8702, p < 0.001)$ and the experience of occupational health problems. When it came to having health difficulties related to one's job, the contextual factors that were statistically significant were proximity $(\chi 2\,(1)\,=\,17.63600, p < 0.001)$ and medical check-up $(\chi 2\,(1)\,=\,3.8711, p < 0.05)$. However, no association was found between the number of years spent in residency $(\chi 2\,(1)\,=\,4.3121, p\,=\,0.099)$, experience $(\chi 2\,(2)\,=\,2.6704, p\,=\,0.127)$, shift $(\chi 2\,(1)\,=\,1.3015, p\,=\,0.124)$, and the incidence of health problems related to one's line of work. The following factors showed statistically significant relationships with having occupational health problems: economic conditions, environmental conditions, safety conditions, health conditions, and environmental conditions $(2\,(1)\,=\,33.7573, p\,=\,0.001, 2\,(1)\,=\,10.0174, p\,=\,0.005, and\,2\,(1)\,=\,10.07616, p\,=\,0.005$, respectively).

4.6 Bivariate Logistic Regression of Health Issues Influenced by Predictor Variables and Employment

Miners in the LSM production and non-production departments were $53.5\%\,and\,54.5\%$ less likely, respectively, to experience occupational health issues linked to the significant factors in the bivariate analysis shown in Table 2 than their counterparts in the ASM production department.

Table 2 shows the bivariate negative log-log regression of goldminers experiencing health problems due to their occupation.

Variables	OR	Robust SE	p-value	Conf. Interval	
Subsector+ Department (ASM Production)					
ASM Non-production	0.461	0.068	0.162	0.208	1.143
LSM Production	0.357	0.177	**0.000**	0.210	0.564
LSM Non-production	0.338	0.148	**0.000**	0.236	0.468
Age (18–24 years)					
24–33 years	1.277	0.067	**0.009**	1.171	1.678

Variables	OR	Robust SE	p-value	Conf. Interval	
34–53 years	1.454	0.183	**0.011**	1.154	2.132
Above 54 years	0.678	0.108	0.322	0.384	1.232
Gender (Male)					
Female	1.601	0.1034	**0.011**	1.108	2.272
Marital status (Single)					
Married	1.342	0.232	**0.001**	1.567	1.978
Education (No formal/Primary/Junior High)					
Senior High	1.098	0.267	0.876	0.865	1.245
Tertiary	0.872	0.105	**0.1054**	0.467	0.865
Experience (1–4 years)					
5–9 years	1.019	0.543	0.889	0.987	1.221
Above 9 years	0.872	0.215	0.107	0.647	1.104
Medical Checkup (No)					
Yes	0.801	0.103	**0.104**	0.567	0.865
Years of Residence (1–4 years)					
5–9 years	1.321	0.286	0.543	0.789	1.641
Above 9 years	0.765	0.215	0.432	0.543	1.601
Shift (No)					
Yes	0.931	0.219	0.543	0.781	1.508
Proximity (No)					
Yes	1.876	0.213	**0.000**	1.533	2.108
Health conditions (Poor)					
Good	0.501	0.107	**0.000**	0.841	0.674
Safety conditions (Poor)					
Good	0.568	0.107	**0.001**	0.641	0.789
Environmental conditions (Poor)					
Good	0.678	0.201	**0.001**	0.567	0.876
Economic conditions (Poor)					
Good	0.721	0.108	**0.000**	0.678	0.887

The probability of occupational health issues among female goldminers was 1.621 times greater than that of their male counterparts, according to compositional variables. In a similar vein, married miners were 1.756 times more likely than single miners to experience health problems at work. Mine workers between the ages of $23-32$ and $33-52$ were 1.556 and 1.643 times more likely, respectively, to experience occupational health concerns than their $17-23$ year counterparts. Additionally, those with postsecondary education had a 28.5% higher chance of not having occupational health difficulties than goldminers with no formal education or simply a primary or junior high school education. Experience was not a significant predictor of the likelihood of work-related health problems.

In terms of contextual considerations, goldminers who willingly underwent routine medical examinations were shown to be 22.5% less likely than those who did not to encounter health problems associated with their work. Similarly, goldminers who lived close to mine sites had a $1.576-$ fold higher chance of experiencing occupational health problems. Years of residency and shift work did not seem to be significant predictors of experiencing health problems related to their profession for goldminers at the bivariate level.

Regarding working conditions, goldminers who reported excellent health were 91.5% less likely than those who reported poor health to experience occupational health problems. Furthermore, goldminers who reported favorable safety, environmental, and economic conditions had a $30.5\%, 32.5\%, and\ 36.5\%$ lower risk of developing occupational health issues than those who reported unfavorable conditions.

4.7 Multivariate Negative Log-Log Regression Model Predicting the Experience of Occupational Health Issues Among Gold Mine Workers

Table 3, a nested multivariate logistic regression, shows the three models' main predictors + compositional model, contextual model, and working conditions model for predicting Ghanaian goldminers' likelihood of acquiring occupationally connected health concerns. Model 1 (key predictors + compositional factors) revealed that miners in the LSM production and non-production sectors were 67.5% and 70.5% less likely to experience occupational health difficulties than their counterparts in the ASM production. But nothing was strongly predicted by ASM non-production. In contrast to their male colleagues, female miners were 2.0998 times more likely to experience occupational health problems when comparing compositional factors. Likewise, married gold miners were 1.671 times more likely than single miners to experience occupational-related health problems. The risk of occupational health problems was 1.821 and 1.723 times greater for goldminers in the $24-33$ and $34-53$ age groups, respectively, as compared to those in the $17-23$ age group. However, experience and education did not show themselves to be statistically significant factors.

Table 3: Negative log-log in many variables Gold mine workers' likelihood of experiencing occupational health issues is predicted by a regression model.

Variables	Model 1: Key predictors + Compositional factors					Model 2: Key predictors + Compositional + Contextual factors					Model 2: Key predictors + Compositional + Contextual + Working conditions				
	OR	Robust SE	p-value	Conf. Interval		OR	Robust SE	p-value	Conf. Interval		OR	Robust SE	p-value	Conf. Interval	
Subsector + Department (ASM Production)															
ASM Non-production	0.561	0.312	0.214	0.291	1.312	0.641	0.217	0.152	0.361	1.125	0.351	0.127	**0.000**	0.214	0.612
LSM Production	0.421	0.104	**0.000**	0.304	0.450	0.341	0.051	**0.000**	0.321	0.401	0.153	0.134	**0.000**	0.512	0.198
LSM Non-production	0.376	0.105	**0.000**	0.189	0.217	0.315	0.030	**0.000**	0.271	0.462	0.201	0.047	**0.000**	0.060	0.181

Variables	Model 1: Key predictors + Compositional factors					Model 2: Key predictors + Compositional + Contextual factors					Model 2: Key predictors + Compositional + Contextual + Working conditions				
Age (17–23 years)															
24–33 years	1.876	0.356	**0.000**	1.431	2.561	1.765	0.976	**0.003**	1.196	2.344	1.786	0.254	**0.021**	1.341	2.705
34–53 years	1.745	0.567	**0.013**	1.087	3.002	1.678	0.367	**0.031**	1.106	2.876	1.876	0.678	**0.008**	1.104	3.321
Above 54 years	0.345	0.321	0.654	0.651	1.476	0.765	0.281	0.872	0.532	1.678	1.156	0.431	0.667	0.673	2.056
Gender (Male)															
Female	1.998	0.400	**0.000**	1.476	2.876	1.712	0.254	**0.021**	1.231	2.673	1.476	0.456	**0.030**	1.010	2.247
Marital status (Single)															
Married	1.487	0.678	**0.015**	1.205	2.279	1.607	0.304	**0.001**	1.165	2.267	1.576	0.327	**0.001**	1.345	2.432
Education (No formal/Primary/Junior High)															
Senior High	1.198	0.109	0.198	0.786	1.698	0.999	0.200	0.678	0.687	1.576	0.876	0.243	0.987	0.678	1.456
Tertiary	1.207	0.199	0.507	0.876	1.678	1.107	0.198	0.589	0.687	1.689	1.098	0.198	0.298	0.789	1.689
Experience (1–4 years)															
5–9 years	0.992	0.153	0.959	0.733	1.342	0.988	0.205	0.578	0.705	1.287	1.018	0.205	1.056	0.678	1.507
Above 9 years	0.600	0.207	0.107	0.460	1.078	0.693	0.158	0.108	0.443	1.084	0.765	0.172	0.233	0.492	1.188
Medical Checkup (No)															
Yes						1.105	0.205	1.078	0.687	1.298	0.799	0.276	0.298	0.587	1.207
Years of Residence (1–4 years)															
5–9 years						1.200	0.207	0.498	0.687	1.567	1.100	0.200	0.678	0.876	1.487
Above 9 years						0.876	0.200	0.568	0.587	1.157	0.876	0.200	0.876	0.785	1.578
Shift (No)															
Yes						1.687	0.287	**0.003**	1.187	2.78	1.876	0.287	**0.001**	1.267	2.900
Proximity (No)															
Yes						1.655	0.156	**0.00**	1.276	2.187	1.687	0.186	**0.000**	1.287	2.157
Health conditions (Poor)															
Good											0.456	0.251	**0.100**	0.256	0.786
Safety conditions (Poor)															
Good											2.823	1.154	**0.10**	1.465	5.200
Environmental conditions (Poor)															
Good											1.456	0.256	0.100	0.100	2.500

Variables	Model 1: Key predictors + Compositional factors				Model 2: Key predictors + Compositional + Contextual factors					Model 2: Key predictors + Compositional + Contextual + Working conditions				
Economic conditions (Poor)														
Good										0.678	0.151	0.156	0.367	1.176

Even when contextual variables were taken into account, the core variables in model 2 were still able to predict suffering from health problems related to work. In this instance, miners in the LSM production and non-production sectors were 77% and 74% less likely, respectively, to experience occupational health difficulties than their counterparts in the ASM production sector. In terms of the compositional elements, it was evident that the likelihood of experiencing health problems associated with one's profession was consistently predicted by age, gender, and marital status. Female miners were 1.567 times more likely than their male colleagues to experience health problems associated with their line of work. Similarly, married gold miners were 1.6605 times more likely to experience work-related health problems than single miners. Goldminers who were between the ages of 24 and 33 $(OR = 1.567, p < 0.05)$ and 33 and 53 $(OR = 1.567, p < 0.05)$ had higher rates of occupational health problems than their peers who were between the ages of 17 and 23. Education and experience didn't seem to be statistically significant factors. Of the contextual factors, goldminers with shift-based schedules and those who lived close to mine sites were more likely to experience occupational health issues (1.678 and 1.674 times, respectively). Medical exam results and the number of years spent in the mining community were not statistically significant factors.

Even after adjusting for working conditions, Ghanaian goldminers reported having occupational health problems in both the LSM production and non-production sectors in model 3. However, a new relationship surfaced, indicating that the components related to working conditions were mediating. In this case, ASM non-production became statistically significant in predicting the presence of health problems related to one's job. This clearly showed how prepared the miner's department and subsector were to predict the likelihood of health problems related to their line of work.

Gender, marital status, and age were still statistically significant compositional factors in predicting having occupational health issues, just like in models 1 and 2. Here, female miners had a 1.4567 -fold increased risk of occupational health problems compared to their male colleagues. Similarly, married gold miners were 1.7054 times more likely to experience work-related health

problems than single miners. Goldminers who were between the ages of 24 and 33 $(OR = 1.757, p < 0.05)$ and 34 and 53 $(OR = 1.852, p < 0.05)$ were more likely to experience occupational health issues than their peers between the ages of 17 and 23.

As with model 2, the contextual factors of shift and proximity were found to be statistically significant in predicting the occurrence of occupational health issues. It was observed that shift workers and those who resided close to mining sites had, respectively, 1.852 and 1.561 times higher odds of occupational health problems.

Regarding working conditions, gold miners who claimed excellent health were 45.5% less likely than those who reported poor health to experience occupational health problems. Goldminers who claimed good safety conditions were 2.999 times more likely to experience health difficulties related to their jobs than their peers who reported poor safety circumstances. Environmental and economic factors did not significantly predict the results.

Simple random and intentional sampling techniques were employed in the study, along with a descriptive research plan that concentrated on ASGM operating operations and on-site field observation. The internet, journals, and periodicals were employed as secondary data sources. We contacted ASGM operators who agreed to take part in the study. For the study, questions were asked of a total of 510 people. 504 participants for the study were chosen using simple random sampling, and ten (10) officers, including two (2) each from the Environmental Protection Agency, Minerals Commission, Forestry Commission, Water Resources Commission, and Asutifi North District Assembly, were chosen using purposeful sampling. The study used field surveys and key informant interviews to collect data from key informants and artisanal small-scale miners. The Environmental Protection Agency, the Minerals Commission, the Forestry Commission, the Water Resources Commission, and the Asutifi North District Assembly officials were interviewed as key informants using semi-structured questionnaires. Through deliberate sampling, the key informants' respondents were selected. Key informant interviews were carried out to gain additional knowledge of the perceived effects of artisanal and small-scale gold mining as well as the functions performed by these specific regulatory authorities in the

research area. To determine the challenges miners faced when implementing OSH techniques, this data was acquired. However, the questions in the field survey were primarily concerned with how OSH regulations were being applied as well as common OHS problems related to small-scale mining operations. Primary data from ASGM operational sites were gathered by the study via a survey. The survey was broken down into two sections: (a) demographic information on the respondents; and (b) data on the causes and effects of accidents that occur while ASGM operations are in place. a) OSH improvement techniques and compliance levels; b) operational activities and OSH management systems for the ASGM business in Ghana. The Likert scale (Likert, 1932), which has a range of one (1) to five (5), was used to evaluate the survey replies. According to the scale, 1 stood for strongly agreeing, 2 for agreeing, 3 for neither agreeing nor disagreeing, 4 for disagreeing, and 5 for strongly disagreeing. Options for not at all, Very often, Often, Indifferent, Not often, and often were also available on the Likert scale. Self-administered questionnaires were used by us. The two sets of questions that made up the questionnaires had both closed-ended and open-ended inquiries. For the closed-ended questions, respondents had to choose from a variety of answers the one that best expressed their ideas. However, there were no more options for the open-ended questions. Responses from respondents were recorded or entirely expressed in writing. Respondents had enough time to carefully consider the questions before responding, ensuring that they gave truthful answers and answered questions as they understood them. Prior to beginning the whole question-asking process, pretesting was done to ensure the questionnaires were correct. The interview guides and questionnaires were serially numbered to ensure the correctness and comprehensiveness of the data collected. Respondents have the freedom to withhold information because their confidentiality and privacy were guaranteed.

V. CONCLUSIONS

In this part, we discuss about the results of our own research on the map of the literature dealing with the meaning of work, we point out where it contributes practically and how it is beneficial to improve the economy, balancing safety and environmental sustainability of Ghana gold mining industry. Our research work is based on theoretical and empirical study. When studying the meaning and meaningfulness of work; this is thus a new approach. Through the examination of theoretical and empirical study, we are able to highlight several unique characteristics of the meaningfulness and meaning of work, and of the change of work meaning, which no other study had managed to

identify before. Our study's objective is to investigate the Occupational Safety and Health (OSH) practices employed in Ghana's precious metals mines in order to inform significant stakeholders and authorities. As a whole, what was found provide an in-depth overview of people's welfare problems in Ghanaian gold prospecting settlements. In our study we employed a statistical approach for sampling all 110 survey respondents. By doing a case study, we use regression and descriptive statistics to examine the relationships between the variables in order to determine the tactics employed to strike a balance between security, financial success, and environmental sustainability. As our research revealed absence of OSH oversight of systems, with mechanical, physical, chemical, biological, auditory, ergonomic, and mental risk factors constituting the majority of causes of crashes. This causes injuries, fatalities, and absences from the workplace. Additionally, there were no references for our study's lack of OSH rules and procedures for bettering precious metals extraction. In dissertation, we also address the manner in which we govern the precious metals extraction project as it alters landscape, as well as the economic success and ecological responsibility of Ghana. These findings show that violations of occupational safety and health do occur in the gold mining sector in the research area. Consequently, the investigation recommends striking a balance between protection, monetary success, and sustainable development. A greater prevalence of protective clothing as well as routine incorporation of aerial photography into governmental evaluations of gold extraction operations are all attainable objectives for achieving requirements for workplace health and safety, boosting Ghana's economic output, and ensuring the longevity of the environment.

The significance of our research work is that the results of analysis might add to corpus of knowledge concerning emerging markets and the incorporation of sophisticated methods for mining for natural assets. Investigation focused on the lack of knowledge among executives in Ghana's gold mining industry on the interactions between social responsibility as a corporate entity and the role of trustee to investors. Providing to the hypothesis of social exchange by means of business social responsibility, encompassing duty of care to participants, environmental impact, and interactions with community across minerals sector, was a further significant component of this research work. Relating those procedures to trustee duty could contribute to consolidating the framework by demonstrating the manner in which social accountability may transform into a mutually beneficial arrangement for an enterprise, as opposed to a disadvantage. Whereas, the scope of our dissertation based on Economic impact of the evaluation that looks at how mining has affected Ghana's economic

development, employment rates, and tax receipts. It examines the mining industry's connections to other economic sectors as well as how much it contributes to the nation's GDP. It looks at the function of benefit-sharing methods, community involvement, and stakeholder engagement in addressing social issues related to mining. The government revenue and fiscal management review assesses the contribution of Ghana's mining industry to the country's tax, royal, and dividend receipts. It examines the difficulties and possibilities associated with budgetary management and the fair distribution of mining revenues.

So, at the end we recommend the review concludes with suggestions for fostering sustainable growth in Ghana's mining industry. It emphasizes the significance of striking a balance between economic growth, environmental sustainability, and social well-being, and avoids getting too particular about individual mining projects or firms in favor of concentrating on the industry's overall effects on the Ghanaian economy. The implementation of the latest cutting-edge approach should be made a policy they are as follows. The greatest environmental dangers are associated with conventional mining methods like open pit and underground mining. These practices should be banned and enforced. Mining waste reuse. Setting up other industries for the use of mining waste. This can help recycle mining waste and help make the environment safe and friendly. Eco-friendly machinery. Cleaning up Old Mines. Eliminating Illegal Mining. Always Wear Safety Equipment. Get Professional Training Follow the Latest Safety Standards. All these recommendations will work when Government sets out a stringent policy that will guide and regulate the whole mining industry of Ghana

Finally, we conclude that the findings of our study as Gold mining industry in Ghana, which is rapidly expanding and widely practiced throughout Sub-Saharan Africa, is an important source of earnings for a large number of people in the regions where it is conducted. Nevertheless, regardless this acknowledged prospective, the extraction of gold presents a number of challenges to the individuals whose partake in it, with the well-being and security of laborers being especially important. Our investigation's goal is to look at the Occupational Safety and Health (OSH) policies in Ghana's gold mining sector and reveal any flaws so that important stakeholders and authorities are aware. The overall findings of this study offer a thorough grasp of the health issues in Ghanaian gold mining villages. Our research field employed a statistical approach for sampling all 110 survey respondents and revealed the absence of OSH system oversight, with mechanical, physical, chemical, biological, auditory, ergonomic, and psychological hazards constituting the majority of accident causes. This results in harm, deaths, and productive absences. In addition, the

research revealed a lack of OSH policies and methods for improving in gold extraction, for which it found not a reference. In our dissertation, we additionally deal with the way we govern the gold extraction process as it alters the countryside, as well as the economic viability and ecological conservation of Ghana. These results indicate that there have been occupational safety and health breaches in the gold rushes in the research region. Consequently, the investigation recommends striking a balance between protection, economic success, and preservation of the environment. A greater prevalence of protective clothing and footwear as well as periodic incorporation of aerial vehicles into governmental evaluations of the gold extraction industry are among the conceivable objectives for achieving occupational safety and health standards, boosting Ghana's financial health and ensuring ecological sustainability.

REFERENCES

[1] Steve Ameyibor, Gold Mining and Land Management in Ghana, http://www.raumplanung.unidortmund.de/geo/download/Abstract%20Vertiefungsentwurf%20Steve%20Ameyibor.pdf (last visited Aug. 12, 2007).

[2] THOMAS M AKABZAA, BOON AND DISLOCATION: THE ENVIRONMENTAL AND SOCIAL IMPACTS OF MINING IN THE WASSA WEST DISTRICT OF GHANA 8 (2000).

[3] Mining Portal of Ghana, The History of Mining in Ghana, http://www.ghana-mining.org/ghweb/en/geologymining/minhistory.html (last visited Aug. 12, 2007).

[4] Thomas Akabzaa & Abdulai Darimani, Impact of Mining Sector Investment in Ghana; A Study of the Tarkwa Region 7 (Natural resources and Sustainable Development Forum-UNCTAD, 2001), http://www.natural-resources.org/minerals/africa/docs/pdfs/Impact%20of%20Mining%20Sector%20Investment%20in%20Ghana.pdf.

[5] Mining Portal of Ghana, Companies with Mining Lease 2001, http://www.mincomgh.org/mining-in-ghana/companies with mining leases.htm (last visited Dec. 21, 2006).

[6] Ghana - Mining: Gold Mining - Overview, http://www.mbendi.co.za/indy/ming/gold/af/gh/p0005.htm (last visited Aug. 12, 2007).

[7] Mining companies such as Ashanti Goldfields merged with AngloGold to form the AngloGold Ashanti.Ghanaian Australian Gold Fields which had in 1997 merged with Ashanti Goldfields became AngloGold Ashanti Iduaprim Mines. Also, Bonte Goldmine, a subsidiary of Akokerri Goldmine a Canadian based mining company, folded up. This period also saw the entry of Newmont Gold mines into the mining sector of Ghana as Newmont GhanaLtd, with its operational areas in the BrongAhafo and the Ashanti Regions of Ghana. http://www.adrbny.com/files/AC4561.pdfhttp://www.anglog

old.com/Investor+Info/Corporate+Activity/AngloGold+Ashanti+Merger+(2004)/
http://www.newmont.com/en/operations/ghana/ahafo/index.asp

[8] Mining Portal of Ghana, Mineral Policy and Fiscal Regime, http://www.ghana-mining.org/ghweb/en/ma/mincom/mcminingnews.html (last visited Aug. 12, 2007).

[9] Dominic Ayine, *The Human Rights Dimension to Corporate Mining in Ghana: The Case of Tarkwa District, in*MINING, DEVELOPMENT AND SOCIAL CONFLICTS IN AFRICA 85 (Third World Network-Africa, 2001).

[10] Ghana: Mining – Overview, http://www.mbendi.co.za/indy/ming/af/gh/p0005.htm (last visited Aug. 12, 2007).

[11] Joyce Aryee, Mining as an Agent of Development: The Role of the Industry, Address at the Corporate Responsibility in Ghana: Extending the Frontiers of Sustainable Development Conference (Sept. 2-4, 2004), available at http://www.ghanamining.org/ghweb/en/home/mainStageParagraphs/0/childParagraphs/04/document/National%20Mining%20Conference.pdf.

[12] Adei D, Addei I, and kwadjosse A. H ,(2011).a study of the effects of mining activities on the health status of people: A Case Study .Research Journal of Applied Sciences, Engineering and Technology.3(2):99-104. Akwatia-Wikipedia, the free encyclopaedia also available athttp://en.wikipedia.org/wiki/Akwatia (2007-01-15)

[13] Bell, J.Doing Your Research Project: Open University Press, Buckingham, 3rd edition (august 1, 1999)

[14] Boivin, Y. A free Response Approach to the Measurement of Brand Perceptions. International Journal of Research in Marketing, volume 3, issue 1, pages 11-17, Elsevier ltd, 1986.Also available at http://www.sciencedirect.com/science/article/pii/016781168690039X

[15] Burns, R.B. (2000), Introduction to Research Methods. Sage Publications Ltd; 4th edition Bush, R. F. and Burns, A.C.Basic Marketing Research, Prentice –Hall, 2nd edition (2007) Cambridge dictionary, available at [http://dictionary.cambridge.org/dictionary/british/awareness]

[16] Creswell, J.W. Research Design: Qualitative, Quantitative and Mixed Methods Approaches, 3rd Ed.Sage Publications. July 15th 2008. Daily graphic, (2011) eastern floods, national catastrophe- minister 25th July, 2011, 03:52:32.available at http://www.graphic.com.gh/dailygraphic/page.php?news=14386.

[17] Denzin, N.K., Lincoln, Y.S. (2005). The Sage Handbook of Qualitative Research. Third edition. Sage Publications, London; New Delhi

[18] Furniss, C (2005).Seizing the Moment: The Great Apes Survival Project. Africa Geographic, July issues: 41-51.

[19] Abbasi, S., 2018. Defining safety hazards & risks in mining industry: a case-study in United States. Asian J. Appl. Sci. Technol.(AJAST) 2, 1071–1078.

[20] Abdulai, A.G., 2017. The galamsey menace in Ghana: a political problem requiring political solutions. Policy Br vol. 5.

[21] Agariga, F., Abugre, S., Appiah, M., 2021. Spatio-temporal changes in land use and forest cover in the Asutifi North District of Ahafo Region of Ghana,(1986–2020). Environ. Challenges, 100209.

[22] Amoah, N., Stemn, E., Jan. 2018. Siting a centralised processing centre for artisanal and small-scale mining – a spatial multi-criteria approach. J. Sustain. Min. 17 (4), 215–225. doi:10.1016/j.jsm.2018.10.001.

[23] Amoako, C., Adarkwa, K.K., Koranteng, K.A., 2021. The politics of artisanal small-scale gold mining (ASM) in the AkyemAbuakwa Traditional Area of Ghana. J. Contemp. African Stud. doi:10.1080/02589001.2021.1957791.

[24] Arthur, F., Agyemang-Duah, W., Gyasi, R.M., Yeboah, J.Y., Otieku, E., Jan. 2016. Nexus between artisanal and small-scale gold mining and livelihood in Prestea mining region, Ghana. Geogr. J. 2016, 1–18. doi:10.1155/2016/1605427.

[25] Aryee B.N.A., Ntibery B.K., and Atorkui E., Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact, 2003.

[26] Asamoah-Gyadu, J.K., 2019. Essays on the Land, Ecotheology, and Traditions in Africa.

[27] Wipf and Stock Publishers. Bansah K., Galecki G., Quaicoe I., Dumakor-Dupey N., Kenneth Joseph B., Grzegorz G., Ishmael Q., and Nelson Kofi D.-D., Occupational health and safety practices in the artisanal and small-scale gold mining sector in Ghana, 2017.

[28] Bansah, K.J., Yalley, A.B., Dumakor-Dupey, N., Jan. 01, 2016. The hazardous nature of small scale underground mining in Ghana. J. Sustain. Min. 15 (1), 8–25. doi:10.1016/j.jsm.2016.04.004, Central Mining Institute in Katowice.

[29] Bansah, K.J., Dumakor-Dupey, N.K., Kansake, B.A., Assan, E., Bekui, P., Nov. 2018. Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. J. Clean. Prod. 202, 465–475. doi:10.1016/j.jclepro.2018.08.150.

[30] Barreto M.L., Schein P., Hinton J., and F. Hruschka, Economic contributions of artisanal and small-scale mining in Kenya: gold and gemstones, 2018.

Adherence to pharmacological treatment of systemic arterial hypertension in primary care

Arthur Vinicius Alves Maciel[1], Tainá Crisóstomo Nunes, Ana Julia Coelho Gomes, Luana Teles Mescouto, Jesiel Menezes Cordeiro Junior, Cristiane dos Santos Lima, Letícia Keren Rodrigues de Souza, Andressa Schmidt do Nascimento, Krysna Gabriely Carvalho Farias, Leticia Esperança de Oliveira Menezes, Lilian Coelho Heringer Diniz, Lucas Oliveira Bezerra, Priscilla Miranda Nunes, Karine Gomes Bandeira Desteffani, Fernanda Silva Hermes, Aniele de Lima Leal, Ana Paula Silva Feio, Thais Costa Valente, Valeria Pereira Rezende de Almeida, Lorenzo de Barros Lopes, Cecília Farias de Figueiredo, Mara Iza Alves Silva, Eduardo Rocha, Edimilson Lopes Cabral, Naylane Sousa Pinheiro, Dienyelle de Nazaré Costa Barbosa, Pedro Thiago Malcher de Amorim Dias, Lucas Batista de Menezes, Isabelle Martins Milhomem, Arthur Araújo Neves, Jaine Cardoso da Silva, Amanda Aguiar Martins Nunes, Amanda Lima Franco e Maria Helena Rodrigues de Mendonça[1]

[1]Centro Universitário Metropolitano da Amazônia, Brasil.

Abstract— Systemic arterial hypertension is defined as a persistent increase in blood pressure levels, which can occur due to a number of factors and is considered a multifactorial disease. Objective: To assess adherence to pharmacological treatment for hypertension in primary care patients. Methods: This is an observational, cross-sectional, individualized study of patients in the hypertension control program at a health unit in Belém do Pará, Brazil, in 2020. A questionnaire was used to collect information, which was then tabulated and evaluated using statistical methods. Results: 42 hypertensive patients were assessed, with a higher prevalence of males, aged between 61 and 70 and with an income of less than 1 minimum wage. Discussion: Patients who needed support to take their medication were the ones who forgot to take it the most, with a statistical difference, as were those who were less informed about the risks of the disease. Conclusion: Hypertension is a public health problem due to its prevalence and the complications associated with its evolution. Investing in raising awareness about the risks of the disease and strengthening primary care are ways of improving patient adherence to treatment for this pathology.

I. INTRODUÇÃO

Nos últimos séculos as tecnologias em saúde foram as ferramentas que mais se desenvolveram e aprimoram suas capacidades diagnósticas, terapêuticas e reabilitadoras, permitindo uma diminuição das moléstias infecciosas e a mortalidade a elas associada. A partir dessa transição do perfil de doenças de maior prevalência destacam-se as comorbidades crônicas não transmissíveis, que aumentam com a idade e são fatores de risco para diversas outras patologias e complicações limitantes (REZENDE & SOUZA, 2016).

A hipertensão arterial sistêmica (HAS), é uma doença que mais se destaca no contexto atual por apresentar alta prevalência, principalmente em idosos, estimando-se que 65% dos indivíduos acima de 60 anos já apresentem a doença, e com perspectivas de aumento nos próximos anos, em decorrência da transição epidemiológica (NASCIMENTO et al, 2021).

A HAS é definida como o aumento dos níveis pressóricos de forma persistente, podendo ocorrer por inúmeros fatores, considerada uma doença multifatorial em que componentes genéticos, epigenéticos, ambientais e sociais estão envolvidos. Os impactos associados a HAS ocorrem pelas alterações que esta pode gerar em outros órgãos, de forma a gerar complicações, crônicas e agudas, como doença renal crônica, doença cardiovascular e entre outras entidades clinicas (MANCIA et al, 2023).

O tratamento para HAS apesar de parecer simples apresenta várias facetas, que envolvem desde o controle dos níveis pressóricos com uso de medicamentos em uma doença que na maioria dos casos é assintomática e que pode levar o paciente a não aderir o tratamento, assim como subjugar a extensão e gravidade da moléstia (TREFOND et al, 2022).

A complexidade do tratamento de comorbidades crônicas envolve desde o reconhecimento da doença, entendimento sobre riscos associados a sua progressão e outros fatores sociais, como acesso as medicações, manejo de efeitos adversos e auxílio no uso das medicações. Nesse sentido, o tratamento da HAS apresenta todos esses fatores por ser uma doença oligossintomática, progressiva e geralmente com acréscimo de medicações para controle, que pode ser um obstáculo para pacientes idosos com dificuldades de atividades instrumentais de vida diária ou mesmo a adesão dos mesmos a polifarmácia, quando há múltiplas Comorbidades (NEGREIROS et al, 2016).

Assim, é necessário avaliar os fatores que influenciam na adesão desses pacientes ao tratamento da HAS, de forma a impedir a progressão da doença e evitar complicações limitantes a ela associadas, para otimizar além das medidas terapêuticas farmacológicas os fatores ambientais e sociais que interferem no controle dessa moléstia.

II. MÉTODO

Trata-se de um estudo observacional, transversal, individualizado e analítico-descritivo que avaliou pacientes do programa de controle de hipertensão arterial e diabetes de uma unidade de saúde em Belém do Pará em 2020, entre janeiro e fevereiro, através de entrevista utilizando um questionário que avaliou sobre fatores epidemiológicos e acerca da adesão ao tratamento de HAS.

Estima-se uma população de 96 pacientes hipertensos cadastrados no programa em questão, considerou-se um intervalo de confiança de 95% e um p-valor de 5%. O processo de amostragem foi por conveniência dos pacientes que frequentaram a unidade para consultas ou procedimentos no período determinado. A análise descritiva utilizou medidas de frequência a partir dos dados coletados e a avaliação estatística utilizou os testes Exato de Fisher e Qui-quadrado, para dados não paramétricos, e teste T para dados paramétricos.

O estudo foi aprovado pelo comitê de Ética em Pesquisa do Centro Universitário Metropolitano da Amazônia com CAAE 25210619.0.0000.5701. Todos os participantes assinaram o Termo de Consentimento Livre e Esclarecido e aceitaram participar voluntariamente.

III. RESULTADOS

Foram avaliados 42 pacientes hipertensos, cerca de 47% dos pacientes com essa comorbidade cadastrados no programa da unidade. A maioria dos pacientes era do sexo masculino (54,7%), com maior prevalência na faixa etária entre 61 a 70 anos de idade (50%) e majoritariamente com renda mensal familiar de até 1 salário mínimo (85%).

Mais de 80% dos pacientes só cursou até o ensino fundamental e possuíam uma média anual de 3 a 6 consultas (50%). Dentre os entrevistados a maioria possuía mais de uma comorbidade (57,1%) e com tempo de doença menor que 10 anos (64,2%).

Todos os pacientes entrevistados relataram bom controle da HAS, apesar de que aproximadamente 60% dos indivíduos apresentava-se com níveis pressóricos sistólicos maiores que 140mmHg ou diastólicos maiores que 90mmH.

Tabela 1. Perfil epidemiológico, social e níveis pressóricos de pacientes hipertensos acompanhados em uma unidade de saúde em Belém, Pará, 2020.

Variáveis	Frequência	% (N = 42)
Sexo		
Masculino	23	54,7%
Feminino	21	45,3%
Faixa Etária		
51 a 60 anos	12	28,5%
61 a 70 anos	21	50,0%
> 70 anos	9	21,5%
Escolaridade		
Ensino fundamental	30	71,5%
Ensino médio	12	28,5%
Ensino superior	0	0%
Analfabeto	0	0%
Renda		
< 1 salário mínimo	36	85,8%
1 a 2 salários mínimos	3	7,1%
> 3 salários mínimos	3	7,1%
Frequência anual de consultas		
< 3 consultas	12	28,5%
3 a 6 consultas	21	50,0%
7 a 10 consultas	3	7,1%
> 11 consultas	6	14,4%
Pressão arterial		
120x80 a 139x89 mmHg	18	42,8%
140x90 a 159x99 mmHg	18	42,7%
>160x100	6	14,4%

Fonte: Protocolo de pesquisa, 2023.

IV.   DISCUSSÃO

O tratamento de doenças crônicas é um grande desafio do ponto de vista de saúde pública, pois estas demandam avaliações periódicas e medidas multiprofissionais para evitar complicações e sequelas da patologia, apesar de não haver um tratamento curativo. Assim os desafios no manejo da HAS destacam-se desde a adesão as medidas de estilo de vida e a abordagem farmacológica, sobretudo quando a doença é silenciosa e progressiva, como a hipertensão.

Variáveis	Orientados quanto aos riscos da doença		p-valor
	Sim (N=30)	Não (N=12)	
Nível pressórico			>0,05
120x80 a 139x89 mmHg	11	6	

140x90 a 159x99 mmHg	16	3	
>160x100	3	3	
Idade			>0,05
51 a 60 anos	9	3	
61 a 70 anos	12	6	
> 70 anos	9	3	
Sexo			0,48
Masculino	12	3	
Feminino	18	9	
Escolaridade			0,0519
Ensino fundamental	24	6	
Ensino médio	8	6	
Deixa de tomar o remédio quando está bem	0	3	0,0045*
Esquece remédios na última semana >3x	0	3	0,0045*
Dificuldade para tomar as medicações	6	3	0,7213
Possui apoio para tomar medicações	9	3	0,7459

Fonte: Protocolo de pesquisa, 2020.

* Estatisticamente significativo

+ Teste T de Studant

Tabela 3. Avaliação de níveis pressóricos, fatores sociais, epidemiológicos e acerca do uso de medicações entre com e sem apoio no tratamento da hipertensão em uma unidade de saúde em Belém, Pará, 2020.

Variáveis	Apoio para uso da medicação		p-valor
	Não (N=30)	Sim (N=12)	
Nível pressórico			>0,05
120x80 a 139x89 mmHg	15	2	
140x90 a 159x99 mmHg	9	10	
>160x100 mmHg	6	0	
Idade			>0,05
51 a 60 anos	9	3	
61 a 70 anos	15	3	
> 70 anos	6	6	
Sexo			1,0
Masculino	15	6	
Feminino	15	6	
Escolaridade			0,2556
Ensino fundamental	27	12	
Ensino médio	3	0	
Deixa de tomar o remédio quando está bem	3	0	0,2556
Esquece remédios na última semana >3x	0	3	0,0045*

Dificuldade para tomar as medicações	6	3	0,2095

Fonte: Protocolo de pesquisa, 2020.

* Estatisticamente significativo

\+ Teste T de studant

O perfil epidemiológico encontrado na amostra é compatível com outros achados da literatura científica, como Çolak et al, 2023, que demonstra maioria feminina, pacientes com faixa etária predominante entr 50 e 70 anos e que cursaram algum grau de ensino médio.

Observou-se que os pacientes que mais esquecerem de suas medicações na última semana, em mais de 3 episódios, foram aqueles que possuem apoio de alguém para o uso das medicações, o que pode demonstrar que a dependência para uso das medicações pode estar associada a maior risco de falhas na adesão ao tratamento, em decorrência da disponibilidade de terceiros para auxiliar e orientar. Nesse sentido, se destaca o papel do próprio indivíduo e da sua indepência para realização de atividades básicas de vida diária como fator importante na adesão e não falha do tratamento. (ADEJUNO et al, 2023; KIM, 2022).

Segundo Lima Filho et al, 2023 a enfermagem desempenha importante papel nas estratégias educativas e no diálogo com os pacientes hipertensos, a viabilizar maior relação de confiança e adesão as medidas de estilo de vida e tratamento farmacológico. Assim, se identifica que um dos fatores essenciais para a maior adesão é o reforço do vínculo do paciente com a equipe de saúde, a garantir a avaliação da adesão do paciente as diversas medidas terapêuticas e plenejamento do plano terapêutico singular.

Na análise da amostra obsevou-se que houve diferênca estatistica entre os pacientes que foram ou não orientados quanto aos riscos da doença, de forma que os que não receberam a orientação tiveram maior taxa esquecimento do uso das medicações ou do não uso quando não sentem sintomas. De acordo com Lima Filho et al, 2023 é fundamental para o paciente hipertenso conhecer a sua condição e o adoecimento como fator importante no esclarecimento de riscos acerca da doença e melhor controle da mesma.

Nesse sentido, se destaca acessibilidade das informações à população, adequando a linguagem e tornando acessível a comunicação, no intuído de tornar o paciente o protagonista de seu tratamento. (LIMA FILHO et al, 2023)

A importância da acompanhamento periódico com os profissionais da equipe de saúde, entre eles o médico e o enfermeiro, ocorre no intuit de estreitar o vínculo e a comunicação e com os pacientes, assim como devidas orientações e avaliação de fatores de risco determinantes para progressão da doença ou não adesão ao tratamento. (LIMA FILHO et al, 2023)

Segundo Lopes et al, 2016 os maiores obstáculos para adesão ao tratamento da hipertensão são a falta de conhecimento acerca da doença, dificuldade na implementação e manutenção das medidas de estilo de vida, dificuldades no acesso as medicações e questões culturais.

A avaliação da qualidade de vida em pacientes hipertensos pode ser subestimada em detrimento dos poucos sintomas nas fases iniciais, entretanto o papel da atenção básica destaca-se justamente nessa fase, com o objetivo de evitar desfechos clínicos desfavoráveis associados a doença. E apesar de as medicações antihipertensivas estarem entre as medicações mais dispensas pelos postos de saúde ainda existem muitos outros fatores que interferem na verdadeira adesão e controle pressórico desses pacientes.

Um estudo nigeriano avaliou as unidades de saúde e verificou que a maioria destas não possuíam os medicamentos em quantidades suficientes para suprir a demanda populacional, além de apresentarem limitações diagnósticas, em que falta de manutenção dos esfigmomanômetros e dos estetoscópios dificulta o diagnóstico e acompanhamento de pacientes hipertensos. Esse fato demonstra a necessidade de fomento a estratégia de atenção primária, com condições adequadas para o exercício do diagnóstico e acompanhamento de pacientes hipertensos de baixa e moderada complexidade. (ADEJUMO et al, 2023)

Çolak et al, 2023 identificou em um estudo em Istambul que as medicações prescritas para pacientes hipertensos há uma predominância de monoterapias, sobretudo a custa de betabloqueadores, o que segundo ele sugere uma exitação na presciração de terapia combinada e dificuldade em identificação e manejo dos efeitos colaterais pelos profissionais.

V. CONCLUSÃO

A hipertesão arterial apesar de ser uma doença prevalente na população e possuir tratamento

disponibilizado na rede pública de saúde possui problemáticas acerca do controle adequado e da utilização de medicações cronicamente. Os pacientes que possuem menor nivel de escolaridade e apresentam maior depedência para utilização das medicações apresentam maior ínidce de falha na adesão ao tratamento farmacológico.

Dessa forma, investir na conscientização da população hipertensa acerca do risco da evolução da doença, fortalecer o vínculo das equips de saúde com os pacientes e a comunidade e fomentar o acompanhamento adequado desses pacientes é uma forma de fortalecer o combate às complicações associadas a hipertensão arterial sistêmica e a melhora na adesão ao tratamento farmacológico.

REFERÊNCIAS

[1] Adejuno, O., et al (2023). Assessment of hypertension service availability in some primary health centres in Nigeria: a mixedmethods study. *BJM Open*; 13, e073833.

[2] Çolak, S. T., Vızdıklar, C., Kaşkal, M., Aydın, V., Ataç, Ö., & Akıcı, A. (2023). Comparison of primary care prescriptions for old and very old hypertensive patients. Turkish journal of medical sciences, 53(2), 572–585.

[3] Ferreira, J.C.V, et al (2020). Qualidade de vida e condições de saúde de pacientes com hipertensão arterial e diabetes mellitus. *Enferm foco*, 12(1), 125-131.

[4] Filho C.A.L, et al(2023). Educação em saúde como estratégia prestada por enfermeiros a pacientes com hipertensão na perspectiva dos cuidados primários. *Arq. Ciências saúde UNIPAR*, 27, 1027-1037.

[5] Kim S. (2022). Effect of primary care-level chronic disease management policy on self-management of patients with hypertension and diabetes in Korea. Primary care diabetes, 16(5), 677–683.

[6] Lopes, E., et al (2016). Controlo da Hipertensão Arterial nos Cuidados de Saúde Primários: Uma Comparação entre Nativos Portugueses e Imigrantes dos Países Africanos de Língua Oficial Portuguesa. *Acta Med Port*, 29(3), 193-204.

[7] Mancia, G. et al. (2023). 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). Journal of hypertension, 41(12), 1874–2071.

[8] Nascimento, M.O. et al. (2021). Factors associated to the adherence to the non-pharmachological treatment of hypertension in primary health care. Rev Bras Enferm, 74(6), e20200173.

[9] Negreirros R.V. et al. (2016). Importância do programa Hiperdia na adesão ao tratamento medicamentoso e dietético e uma unidade de saúde da família (USF). Revista Universidade Vale do Rio Verde, 14(2), 403-411.

[10] Rezenda, E.P, Souza, L.E.P.F. (2016). Análise da implantação do sistema de cadastramento e acompanhamento de hipertensos e diabéticos em municípios da bahia - 2013. Revista Baiana de Saúde Pública, 40(2), 9-26.

[11] Trefond, J., Hermet, L., Lambert, C. et al. (2022). Home blood pressure monitoring and adherence in patients with hypertension on primary prevention treatment: a survey of 1026 patients in general medicine in the Auvergne region. BMC Prim. Care 23, 131.

Evaluation of the Algerian pilot program of colorectal cancer screening by immunological test

Chahira Mazouzi[1], Radia Benyahia[2], Esma Kerboua[3], Meriem Belloul[4], Malha Laoussati[5], Mokhtar Hamdi Cherif[6], Kamel Bouzid[7]

[1]Department of medical oncology university of bejaia
Email: chahira.mazouzi@univ-bejaia.dz
[2]Department radiology cpmc university of Algiers
[3]Department oncology cpmc university of Algiers
[4]Department of gastroenterology oncology university of bejaia
[5]Department of epidemiology university of bejaia
[6] Department of epidemiology university of Setif
[7]Department radiology cpmc university of Algiers

Abstract— The results of various randomized clinical trials have led to the establishment of pilot or organized colorectal cancer screening programs in several countries. To date, there is no mass screening program or strategy for colorectal cancer in Algeria for the average risk population. Thus, our work problematic was composed: mainly on the feasibility of implementing a colorectal cancer screening program. The objective of our study is to carry out an organized mass screening strategy for colorectal cancers in the wilaya of Bejaia as a pilot project within the framework of the 2015-2019 cancer plan. The criterion of judgment of this program established is the Rate of participation (TP) of the target population which must be higher or equal to 40%. The program developed is evaluated by performance indicators. The participation rate was 30.02%. 17(6‰) people are screened for colorectal cancer. The mean age of his patients is 59.76 years +/- 8.2, a median of 57 years and a mode equal to 50 years.24.24% people with advanced adenomas. At the end of our study in this pilot wilaya designated by the 2015-2019 cancer plan, it appears that the organized screening program is feasible subject to the following conditions: - Expand the pilot phase of a population-based screening in other sites in Algeria. - Institutionalize the colorectal cancer screening program at the local and national levels. - Provide a dedicated budget for this project. - Create a colorectal cancer mortality registry at the regional and national levels

I. INTRODUCTION

The International Agency for Research on Cancer IARC estimates the global cancer burden to be 18.1 million new cases and 9.6 million deaths in 2018. Colorectal cancer is common in industrialized countries, particularly in Western Europe and North America, and in Oceania. It is less common in South America, Africa and Asia. In the US, Colorectal Cancers (CRC) account for 9.7% of all cancers, with an estimated 179,771 new cases in 2018.[1] In Africa, colorectal cancer remains a disease that ranks first among cancers. The highest incidence is observed in South Africa with 6,937 new cases estimated in 2018 by the Globocan network; in Niger observes an incidence in the same year estimated at 6690 per 100,000 inhabitants;

in Egypt, the incidence is estimated at 5393; Morocco records 4118 new cases. Algeria is placed the 3rd country in terms of incidence in Africa and the first in North Africa with 5537 new cases in 2018, according to the same sources of estimation Globocan 2018. In Algeria, the incidence of colorectal cancer in 2016 is 13.7 in men and 14 in women per 100,000 inhabitants. Analysis of the progression of the disease shows an increasing trend with a CPA of +7 each year, and also increases with age, The highest incidence is observed in the wilaya of Bejaia or it is 16 in women and 23.5 in men per 100,000 inhabitants, followed by the wilaya of Constantine with an incidence of 14.6 in women and 17.4 in men per 100,000 inhabitants. The lowest incidence is observed in Ouargla and Skikda with respective incidences of 4.6 -7.4 in women and 9.5-7.5 in men per 100,000 inhabitants, according to the Réseau Est et Sud Est, Algeria 2015. [2] In our country, colorectal cancer (ccr) fulfills the conditions that the WHO has established in the framework of detectable cancers: - It is a frequent cancer in Algeria (first position among cancers in men, and the second in women.) - Serious (the mortality rate increases by this cancer in Algeria) - Preceded in 60 to 80% of cases by an adenomatous polyp whose removal prevents malignant transformation. Our problem was built after the publication of new epidemiological data published by the network east and south east national in 2016 which concludes to an increase in the annual percentage of 7% of the incidence of colorectal cancer, in 2030 the data of incidences and mortality will be identical to those observed today in industrialized countries, the preparation of a strategy which aims to detect the disease at an early stage or then precancerous lesions, would be to our reflection necessary in order to check it on the Algerian ground the feasibility of a mass screening? The aim of this study is not only to identify the failure of the screening process before its extension soon, but also to determine the lack of diagnostic and therapeutic tools in terms of digestive endoscopy equipment and of the specialist physicians concerned by the pathology. From this general context, several problematic subchapters follow that we translate by the following questions: which feasible strategy to plan: the screening is addressed to which population? from which age the population is concerned by this screening? What are the necessary means for its execution? What is the diagnostic and therapeutic network envisaged? and how long will it take to treat the screened patients? Who are the partners involved in this project and what are their expectations? Evaluation: when to evaluate? Who and how to evaluate? By what to evaluate Duration of the pilot study and deadlines? The results of various randomized clinical trials have led to the establishment of pilot or organized colorectal cancer screening programs in several countries. To date, there is no mass colorectal cancer screening program or strategy in Algeria for the average risk population. We propose a study on the feasibility of a mass screening program for colorectal cancer in a sample of population at average risk representative of the wilaya of Bejaia constituted of three pilot daïras. The criterion of judgment of this program established is the Rate of participation (TP) of the target population which must be higher or equal to 40% in our study. The objective of this work was to evaluate the effectiveness and feasibility of the pilot study of organized colorectal cancer screening in the wilaya of Bejaia, in view of a global strategy of mass screening.

II.   MATERIALS AND METHODS

This is an epidemiological study of the screening type. Requiring the citizen's agreement and consent by signature or fingerprint. Definition of eligible subjects: Male or female persons aged between 50-74 years with an average risk of developing colorectal cancer and living in the following three Daïra: Souk El Ténine (SET), Adekar daïra, Amizour commune. Place and period of the study: the public health establishment of proximity (EPSP) of Souk el etenine, EPSP of Amizour, EPSP of Adekar, the University Hospital of Bejaïa. Duration of the study : from January 02, 2017 to February 28, 2019 or, 26 months. Number of subjects needed: In our mass screening study, the number of subjects must aim at a sufficiently large population, with homogeneous elements. The risk of error is minimized when the population is exhaustive. Nevertheless, other methods could be used such as random sampling and its variants, cluster sampling, systematic sampling, stratified sampling, and numerical sampling. Since the target population in the wilaya of Bejaia is estimated at 100,000 inhabitants, 10% of the population corresponds to 10,000 people. We are working on a representative sample of 10,000 citizensand we want to reach 40% of this population, which corresponds to 4,000 citizens in the three daïras. This study was carried out on a representative population of the general population, i.e. 10% of the target population, which represents 10,000 citizens residing in the following daïras -Daïra of Souk el etenine composed of two communes : Souk el etenine and Melbou installed at the outlet of Assif Augrioun on the coast with a target population of 4000 inhabitants. -The Daïra of Adekar: located in the northwest of the wilaya of Béjaïa and borders the wilaya of Tizi-Ouzou. Located in a mountainous region going up at an altitude of 859 m, the daïra includes the three communes of Adekar, Taourirt Ighil and Beni Ksila and the target population concerned is 2000 citizens. -The daïra of Amizour on its commune

Amizour with a target population of 4000 citizens. These three daïras were chosen for the following reasons: -Each daïra represents a different geographical model from the other: coastal, inland, mountainous. - The urban, suburban and rural characters; exist in each of the selected daïras. The target population in each daïra is exhaustive insofar as the daïra of Souk el Tenine is concerned by its 4,000 inhabitants, the daïra of Adekar is represented by its 2,000 inhabitants and the commune of Amizour groups together 4,000 inhabitants. These inhabitants are over 50 and under 74 years old. In sum, we obtain the figure of 10,000 citizens, which corresponds to the number necessary for the realization of our study. The questionnaire is one of the main instruments in our study, in particular to identify eligible and ineligible persons with a guidance of a course of action based mainly on the existence of symptoms or personal or family history of colorectal cancer. The colorectal cancer screening test used in our study is a rapid chromatography immunoassay that allows for the qualitative detection of blood in stool. In order to ensure that our colorectal cancer prevention and control program runs smoothly, we had to initiate a methodical organization. Before proceeding with the development and implementation of the program, it was necessary to ensure the political will in favor of this pilot operation, Our prevention strategy includes diagnostic and therapeutic steps, it was necessary to check first the functioning of the services practicing colonoscopy and biopsy (for the examination of presumed invasive lesions) as well as histopathology laboratories, but also the services for the management of patients with invasive cancer, including the carcinological surgery service, medical oncology service and radiotherapy (prescribed for cancer of the lower and middle rectum). A multidisciplinary consultation meeting was created on January 05, 2018 and is an integral part of all treatment services. The smooth running of the prevention program required qualified personnel, equipment and materials in working order. In addition, they must be closely linked to ensure that patients receive the appropriate care and continuity of care that the ethics of screening require. It was also necessary to designate other hospital structures even outside the wilaya to ensure replacement in case of equipment failure or to fill the lack of specialized medical staff, in order to guarantee the diagnostic and therapeutic aspect of the colorectal cancer screening process and its continuity,The general practitioner carries out a questionnaire among the voluntary citizens to eliminate the high and very high risks of developing colorectal cancer (IBD, PAF, Lynch syndrome etc. ....) or to eliminate the population that presents a digestive symptomatology that can orientate towards colorectal cancer (rectal bleeding, etc. ....) The

evaluation criterion for this program is the Participation Rate (PR) of the target population, which must be greater than or equal to 40%. Statistical analyses were performed using SPSS 20.0 statistical software. Continuous quantitative variables were expressed as mean ± standard deviation. For the comparison of groups, we used a Pearson Chi-2 test for categorical variables and a t-test for continuous quantitative variables. For the study of risk factors, univariate analysis with a $p \leq 0.20$ was retained for multivariate analysis. The multivariate analysis allowed the calculation of Odds Ratios with 95% confidence intervals (IC95%). For the entire statistical analysis, the threshold of significance retained was $p < 0.05$.

III. RESULT

The mean age of the participating population is 59, 72 years (+/- 6.63). 50% of this population is under 60 years of age; the median is 60 years of age, and the most frequently found age in the series is 50 years (Table1). 41% of the participating population resides in rural areas, while 59% of the population resides in urban and suburban areas. 13.7% are employed, 41% are retired and 45.3% are not employed, 92% of the population have social security. The most frequent type of social security found in the participating population is the CNAS in (2598)86.54%.

I Evaluation of the participation rate: We collected, on the basis of 10,000 guests, 3002 files from citizens aged between 50 and 74 years. That is to say a total participation rate of : 30.02%. Fig1 illustrates the participation rate of the target population in relation to the general target population and in relation to the target population in each daïra. 1735 people, i.e. a rate of 43.38% of the target population of the daïra of Souk el Tenine, participated in the Screening, which corresponds to a rate of 57.8% of the total number of participants (3002). The lowest rate is observed in the daïra of Adekar with a rate of 18.75% and a rate of 12.5% of the total number of the participating population (3002). The age range of the highest participating population is between [50-54] years, then the age range between [60-64] years, the participation rate is decreasing with increasing age of the population of [65-74] years, (Figure1), The participation rate is decreasing with increasing age in the commune of Amizour versus increasing with age in the daïra of Souk el Tenine, in the daïra of Adekar the participation rate is stable in all age groups of the participating population. The chi-square test did not reveal any significant difference between the two sexes in the participating population. The sex ratio is 0.81. The analysis of the participation rate by gender in each daïra does not show a significant difference (p= 0.25). The sex

ratio = 0.81. The participation rate curve is decreasing (Figure 2), along with the curve for the number of outreach activities. We studied the correlation between these two curves by applying a Pearson correlation coefficient R2= 0.99. Its positivity shows us that there is a true correlation between the number of outreach actions and the number of participants calculated per month during the year 2017. The correlation index is also calculated for the months of May, June and July of the year 2017 and shows a correlation R2= 1 The correlation index calculated regarding the month of January, February and March of the year 2018 and shows a correlation R2= 1 The correlation coefficient calculated for the year 2017/2018 by quarter finds a R2= 0.86 The number of participants correlates with the number of awareness action. The total participation rate of general practitioners is 42% in the two health sectors of the daïras concerned by the mass screening of colorectal cancer, 85% of people came for colorectal cancer screening, and 15% came for another reason for medical consultation and agreed to be screened when proposed by the physician. Results of the immunological test in the eligible population 217 persons, i.e. a rate of 7.2 % have a positive test, while 10.6% (317) of individuals are excluded from the study due to the presence of symptomatology suggestive of colorectal cancer or a personal or first-degree family history of colorectal cancer. 2468 people had a negative immunological test result, which represents a rate of 82.2% of participants (Figure 3). It is noted that the highest rate of positive tests in the study population is in the [60-69] age group, followed by the [50-54] age group, and the lowest rate is in the [70-74] age group. There were 17 cancers detected out of the eligible population (2685) for mass screening, or a rate of 6‰ of colorectal cancer. The mean age of those screened for colorectal cancer was 59.76 +/- 8.2 years, a median of 57 years, and a mode equal to 50 years. The sex ratio =0.89. The peak age of detected colorectal cancers is in the [50-54] age range, followed by the [65- 69] age range, with the lowest rates observed in the [55- 64] age range (Figure 4). Polyps and Adenomas Detected: The number of people with polyps 89(3.5%) of the eligible colorectal mass screening population (2686) is carrying at least one colorectal polyp. 37% of the population with polyps have at least one adenoma and 15% of the population with test+ have at least one adenoma, while 1.3% of the participating population have at least one adenoma. 30% of the adenomas with test+ have villeous type adenomas, 20% of the adenomas are tubulo-cultivated, and 50% have tubular adenomas. The statistical analysis of the resected adenomatous polyps according to histological type and

colorectal topography (Figure 5) shows us that the villous histological type is preferentially located in the sigmoid part with a rate of 27.3%, then it is located in the right colon with a rate of 9%, then also in the left colon and rectum with a rate of 3%. The tubular histological type is located in the sigmoid with a rate of 9%, then in the rectal with a rate of 6%, and also in the right and left colon with a rate of 3%, the tubullo-cultivated histological type is located in the sigmoid with a rate of 15%, then in the right colon with a rate of 9%, and also in the rectal and left colon with a rate of 6% of the screened population. Statistical analysis of resected adenomatous polyps according to histological type and according to the Paris classification shows us that the majority of villeous types are pedunculated (41.4%) then sessile (8.6%). Tubular types are pedunculated in 13.8% of cases and 10.3% of cases are sessile, tubullo-city types are pedunculated in 17.4% of cases and 8.6% of cases are sessile. According to the statistical analysis of the histological types of adenomas according to their size, we note that the most voluminous histological types (> 20 mm) encountered are the villeous and tubular adenomas in 12% of the cases, while the tubullo-cultivated ones are in this size range in 3% of the total adenomas. Among the villeous adenomas, 53.85% have a size between [10-19.9] mm and in 31% are >20mm versus 15% are < 9.9 mm Among the tubular adenomas, 50% have a size between [10-19.9] mm, and 40% have a size>20mm, versus 10% have a size 20 mm. Table 2 analyzes the adenomas according to the following variables: size, degrees of dysplasia, and histologic type. The Test: The rate of tests reported as unanalyzable is 8.5% (229) of the immunoassays were failing, the predictive values of the cancer screening test = 7.8% The PPV for detecting advanced adenomas for the test used is 3.23%, the PPV for detecting adenomas for the test used is 15.20%, the PPV for detecting polyps for the test used is 90.32% The number of colonoscopies performed was 189 (87%) of the indicated colonoscopies for mass screening (i.e., 217). The number of indicated colonoscopies not performed was 28 (13%). The reason for not performing the indicated colonoscopy of positive tests was mainly the refusal of the persons to perform the procedure with a rate of 6.4% (14). A rate of 2.76% of the population have formal contraindications to the performance of colonoscopy (people under anticoagulant therapy, major heart disease) while 3.7% of people are lost to follow-up.

IV. DISCUSSION

We propose in this study a pilot strategy of mass screening for colorectal cancer whose aim is, firstly, to answer questions of feasibility and acceptability on the Algerian

ground, and secondly to determine the specific performance indicators established by the international scientific communities. Our strategy is defined by inviting an asymptomatic population aged 50 to 74 years without any personal or family history of first-degree colorectal cancer every 2 years to perform a qualitative immunological test at the level of proximity health structures of the three designated pilot daïras. The persons having obtained a positive test are invited to carry out a total colonoscopy at the level of the CHU Khellil Amrane by trained endoscopists. This study was conducted between January 2017 and February 2019. The European Commission, in a directive of December 2003, recommends a 2-stage screening strategy based on performing a fecal test every 1 to 2 years in the 50-74 age group [3]. More nuanced recommendations, considering recent work, were published by experts at the European Commission in 2010. The rate should not exceed 2 years and the "minimum" target is the population between 60 and 64 years old, each member state being free to extend it to younger or older age groups depending on its resources. Only England, Scotland, Finland, and the Czech Republic had an organized program covering the whole country [4]. In the other European countries, the implementation of screening has been very gradual. Initially, the FOBT was used in France, Finland, the United Kingdom, Belgium, and Italy, and gradually the immunological test replaced the gFOB. Luxembourg and Poland favored colonoscopy but introduced a strategy based on the immunological test. Some countries such as Denmark, Norway, Hungary, Spain and Portugal do not have a clearly defined strategy for CRC screening but have started pilot studies or clinical trials that are being validated. In the United States, there is no mass screening campaign, the American cancer society recommends either immunological tests every year, or a choice of colonoscopy every ten years or flexible sigmoid endoscopy every three to five years in those over 50 years of age. No pilot studies have been published or national recommendations have been found in the literature for countries in North Africa or the Middle East where the epidemiological parameters of mortality are poorly known. Table 3 illustrates some examples of the status of colorectal cancer screening in some countries in comparison with Algeria. 10.6% (317) of the target population were excluded from the study because of the presence of symptomatology suggestive of colorectal cancer or a personal or first-degree family history of colorectal cancer. According to the information collected by the pilot management structures in a study conducted in 2012 at the Institut de veille in France concerning a total population of 9.1 million women and men aged over 50 and under 74 years. The rate of medical exclusions from

the organized screening program was 10.7% over this period, or just over 1,825,000 people. Other pilot studies have found the same figures for the population not eligible for mass screening and who undergo total colonoscopy without screening. This category of population deserves more attention in our country by conducting a specialized study to know its epidemiological profile and by organizing a systematic review on the planning of a targeted screening of high and very high-risk families [5]. The screening is aimed at people aged 50 to 74 years. This is consistent with the requirements of the Guidelines and with international practice. At the international level [6] , the question of age is a major concern. Different situations can be observed: - In France, the program includes the population aged 50 to 74 years. The French High Authority for Health notes that better identification is needed for men and women aged 70 to 74. - The Canadian Task Force on Preventive Health Care recommends the reference ages of 60 to 74 years (primary recommendation) and 50 to 59 years as a secondary recommendation (no screening beyond age 75). - In Germany, a program modulates the choice of method according to age: from 50 to 55 years, immunological test; from 55 years, colonoscopy. - In the Netherlands, the Heath Concil of the Netherlands (2009) recommends that the age range be 55 to 75 years. - In the United States, the updated recommendations (update 2018, American Cancer Society) recommend screening from age 45 to 75. - In Switzerland, health insurance legislation recognizes the 50-69 age range for ccr screening. Discussions are underway to extend screening to 74 or 75 years [7]. In our study, the results of the frequency of colorectal cancers show that the average age is located 59.76 years +/- 8.2 and the most frequently found age is (mode) in the series is 50 years. The age limit for access to screening is 50 years, and it is consistent with practice. Several countries refer to it. However, the scientific literature shows the existence of analyses and discussions concluding that it would be beneficial to lower the age of entry to 45 or even 40 years [8]. There are no precise rules in this respect. It is up to the health authority to determine the age of entry according to the constraints of program implementation (care capacity, available resources). It is proposed that the age of entry into mass colorectal cancer screening be lowered to 45 years, which is 5 years earlier than the age of entry (50 years) found in our study. The literature points out that various obstacles to participation must be carefully considered, as participation depends on many factors: political (will and means), cultural, organizational, financial, standard of living, population expectations, and the quality of the information and invitation process. Various studies have highlighted, through the choice of

organization or method (as for other prevention programs), factors that facilitate or restrict the participation of the population. As the effectiveness (and efficiency) of a program depends on the participation rate, these issues require special attention [9]. The barriers identified at our level are: - Culture and perception of health prevention influence the effectiveness of a Program, - cancer is a taboo disease that means death; the concept of cure is not possible due to the lack of knowledge of colorectal cancer and its carcinogenesis process by the citizen. - The fact of not feeling concerned because of one's state of health (absence of symptoms) is not to be underestimated. - Family, social and economic situation. - Gender: in our study we did not find a significant difference in participation between the two sexes. However, in Europe or in the USA, men are less concerned about screening than women. Women can play a key role in informing and encouraging participation, particularly because of their experience with breast cancer screening as a successful program. - Age: the oldest members of the target population (65-74 years old) are more reluctant. – Precariousness This category of the population generally has an average general state of health and is often less informed and aware. - The program's information and organizational arrangements are insufficient for continuity and stability of participation, as shown in the graphs - Fear related to the screening result. A total of 217 people tested positive, for an overall positive test rate of 7.2% (among those who tested analytically). For men, the positive test rate is 7.7%. For women, it is 8.4%, there is no significant difference in the results of the immunological test between men and women (p=0.0.52). The rate of positive tests did not increase with age. For each age and sex category, it is highest in the 60-64 age group, then in the 50-54 age group, and lowest in the 70-74 age group. In Europe and in an evaluation of a pilot study conducted in 2013 at the Institut de Veille Sanitaire in France [10], the rate of positive tests increases with age. For each age and sex category, the comparison between the age ranges of positive tests in our study did not find statistical significance (p=0.197), The results of the immunological test were compared between medical facilities, by applying the chi-square test, the test results were significantly different between facilities. The sensitivity and specificity of the screening test used remains low and deserves consideration in the future: First-generation qualitative immunoassays have a positivity threshold set by the producers. In our study, it is 50 ng/ml, these tests can be used in the first pilot studies in order to determine the difficulties and obstacles that can be encountered in the field before generalizing these strategies in countries with a high incidence and mortality of colorectal cancer and a

high cost of therapeutic management. The accessibility, the feasibility and verification of the diagnostic and therapeutic network are factors in the success of mass colorectal cancer screening. Pilot studies in general aim to verify its parameters influencing participation. The detection rate of colorectal cancer is equal to an average of 6 ‰. It is more frequent in women 53% than in men 47%, but statistically no difference is observed between the two sexes. This rate is high compared to what is reported in the literature; in France the rate of detected cancers is 1.7‰, in Germany in a pilot study is 2‰ [11]. The Sex ratio is 0.89. The average age observed in our study is 59.76 +/- 8.2 years. The most common age observed is 50 years. No statistical variability was observed between the cancers detected according to the institution or the area of residence. The topography of the cancers detected in our study did not differ from the results observed in other studies worldwide: sigmoid 47% and rectum 24%, right colon 17% and left colon 12% . It can be noted that for the age group most affected is 50-54 years, then the one from 60- 74 years. In a pilot study carried out in England in 2010, the same age groups were observed [12]. Although time to colonoscopy after a positive screening test is an evaluation criterion for the screening program, few studies have analyzed the time to colonoscopy after a positive test. It is important to identify the factors that may delay colonoscopy and the potential impact of longer wait times on the detection rate of colorectal tumors. According to the European guidelines for quality assurance in colorectal cancer screening and diagnosis, at least 90% (ideally 95%) of individuals with a positive test in an organized screening program should have access to colonoscopy within 31 days (evidence and recommendation level: VI-B) [13].According to the Canadian National Colorectal Cancer Screening Network, at least 90% of individuals with a positive test result should receive colonoscopy within 60 days [14,15]. In the Bejaïa experience, the average waiting time for colonoscopy was 28.16 days, which is in line with international recommendations on waiting times for screening colonoscopy; 75% of the population who required a colonoscopy after a positive test had their colonoscopies after 33 days of waiting, the minimum waiting time was 6 days and the maximum 386 days with a median of 25 days A Californian study evaluated the impact of the delay between the date of the fecal immunoassay (FIT) and the performance of the colonoscopy on 70124 FIT- positive patients, 2191 of whom had colorectal cancer, including 601 at an advanced stage (Stage III or IV). Cancer rates were similar (3 to 3.4%) in the 1-month, 2-month, 3-month, 4-6-month, and 7-9-month periods. However, the rates were

significantly higher beyond 10 months (4.9%) and 12 months (7.6%). Similar results were observed for advanced adenomas. For stage III and IV cancers, the rates up to 7 months ranged from 0.7 to 1.3% but increased significantly to 1.9 and 3.1% after 10 and 12 months respectively [16]. The waiting time for curative surgery was the prerogative of our study, with waiting times that could exceed 400 days, with an average waiting time for surgery of 115 days+/- [17] 163,265. A rate of 25% of patients were operated on within a minimum of 18 days, while 75% were operated on within an average of 97 days Weaknesses of the study: - No budget was reserved for this project, which generated delays in its execution. - The study was carried out as a monocentric study; no comparison is possible in Algeria. - The information system is insufficient. - Training did not reach all the actors involved in the project, anatomopathologists and surgeons were not evaluated. - Lack of data in the anatomopathology reports and the reports of carcinological surgery and colonoscopy due to the absence of standardized protocols in each specialty. - Lack of risk analysis prior to program development for each step of the colorectal cancer screening process. Strengths of the study: -A major strength is that the study reflects the reality of the health field in the wilaya of Bejaia using routine health care, which allows an assessment of the feasibility of colorectal screening in a country where the health sector is experiencing significant deficiencies. - The pilot phase of the proposed colorectal cancer screening program can be considered positive and successful. Although imperfect, the program is unanimously considered important for the Algerian public health system and the population. Beyond the imperfections, errors and shortcomings that remain to be corrected, the pilot study also allowed for the testing of screening methods and procedures, and organizational modalities. This first national study, and one in North Africa, could serve as a point of comparison in future scientific studies of mass screening for colorectal cancer.

V.   FIGURES AND TABLES

Table.1: Age *Description* of Participant Population

Average	59.72 ans +/- 6,63
Médian	60 ans
Fashion	**50 ans**
Minimum	50 ans
Maximum	74 ans
Percentiles 25 %	54 ans
50 %	60 ans

75 %	65 ans
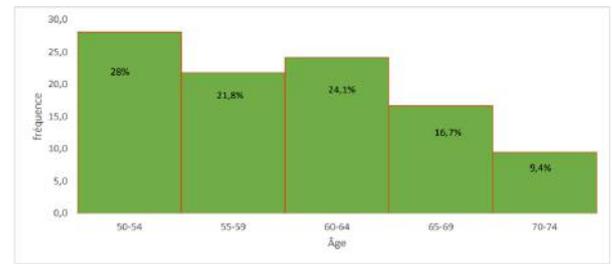
Fig.1: Overall participation rate by age

Fig.2: Number of outreach events and number of participants 2017/2018.
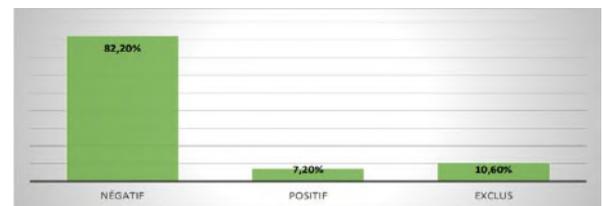
Fig.3: Immunoassay results
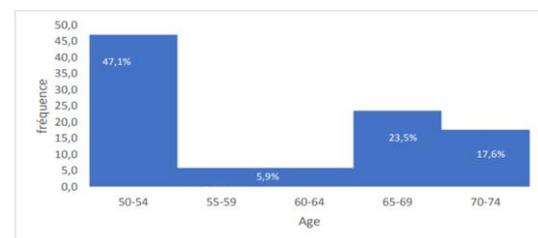
Fig.4: Distribution of colorectal cancers by age group

Tableau 2 : Histological type of adenomas according to their sizes and degrees of dysplasia in people with at least one adenoma

Sign of dysplasia	Type of adenoma	class by size			Total
		<=0,99cm	1-1,99 cm	>=2 cm	
No	TUBULAR	0	0	1	1
	TUBULAR VILLOUS	1	0	0	1
	Total	1	0	1	2
High	VILLOUS	2	4	4	10
	TUBULAR	0	4	2	6
	TUBULAR VILLOUS	1	4	1	6
	Total	3	12	7	22
Down	VILLOUS	0	3	0	3
	TUBULOUS	1	1	1	3
	TUBULAR VILLOUS	3	0	0	3
	Total	4	4	1	9
Total	VILLOUS	2	7	4	13
	TUBULAR	1	5	4	10
	TUBULAR VILLOUS	5	4	1	10

Table 3 : Status of organized colorectal cancer screening (2017).

Country	PODCCR status*
Algeria	Pilot study of feasibility and acceptability by iFOB, FIT in 03 Wilayas (2017), No recommendation by the 2015-2019 Cancer Plan
Australia	Implementation of a national colorectal cancer screening program based on population 2004
Belgium	Feasibility study on screening using FOB since 1990. No national population-based screening program
Canada	No population-based pilot study has been conducted, mass screening recommended
France	Pilot studies in 23 departments (1999), mass screening recommended >50 years -74 years 2009 by FOB then replaced by FIT (2015)
Germany	No mass screening is recommended, centralized data, opportunistic screening >55 years old by an immunological test or colonoscopy /5 years Pilot study not
Japan	carried out, mass screening recommended since 1990, low participation rate <25%
Italy	Pilot feasibility study in 21 departments Mass screening recommended by an immunological test.
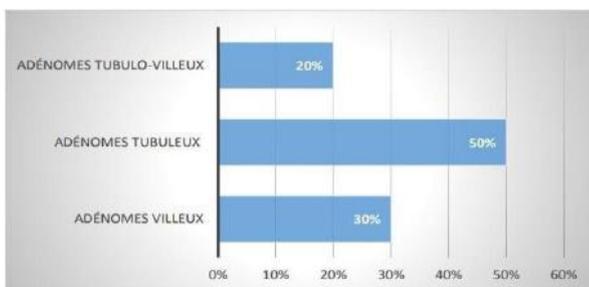
Fig.5: Distribution of adenomas according to their histological appearance

VI. CONCLUSION

The evaluation of the pilot phase of the organized colorectal cancer screening program in the wilaya of Bejaia, from 2017 to 2019, addresses the following issues: 1. Evaluate the organization and functioning of the 2017-2019 pilot program. 2. Evaluate the screening modalities selected and their effects. 3. Analyze the positioning of the actors involved,

4. Reorganization of the national committee into groups of experts: endoscopists, oncologists, anatomopathologists, and definition of the tasks assigned to them 5. Analysis of the effects in terms of prevention and health promotion 6. To propose possible adjustments for the sustainability of the program. 7. Substitution of the qualitative immunological test by an automated test (We have started the substitution of the qualitative test by the quantitative test of colorectal cancer screening, and we have made a first evaluation of the 80 volunteers exposed in appendix 14. 8. Improvement of the quality and the means for the transmission of the message to the target population. 9. Elaboration and distribution of the self-evaluation questionnaires for the periodic general practitioners. 10. Elaboration and distribution of self-assessment questionnaires for citizens on a website. 11.Elaboration of documents containing standardized information on the endoscopy and histology reports of the polyps detected in the appendix 16 a proposed report 12. Extension of the pilot project by 2 years We therefore propose that, by regulation, an extension of the project be accompanied and financed to achieve its generalization, 13. Implement other national pilot studies based on the results of the study in the wilaya of Bejaia 14. Financing and fund dedicated to colorectal cancer screening 15. Implement screening strategies for the population at high risk of developing colorectal cancer.

REFERENCES

[1] International agency for research on cancer Globocan 2019 https://gco.iarc.fr/

[2] Hamdi-Cherif M, Sekfali N, Coleman MP. Incidence of cancer in the wilaya of Setif, Algeria. Bull cancer. 1991; 78(2):155-167.

[3] Von Karsa L, Patnick J, Segnan N, Atkin W, Halloran S, Lansdorp-Vogelaar I, et al. With European Colorectal Cancer Screening Guidelines Working Group. European guidelines for quality assurance in colorectal cancer screening and diagnosis: overview and introduction to the full supplement publication. Endoscopy. 2013;45(1):51-9.

[4] Faivre J, Tazi MA. The role of the general practitioner in colorectal tumor screening. Gastroenterol Clin Biol 1995; 19: 361-3.

[5] Potvin É, Gosselin C. Immunochemical test for occult blood in stools: Determination of a positivity threshold to start the PQDCCR demonstration projects. National Institute for Health and Human Service Excellence. 2012;1-42.

[6] YUTIAN ,ELHAM KHARAZMI Gastroenterology, Volume 159, Issue 1, July 2020, Pages e18-e19; doi.org/10.1053/j.gastro.2020.03.063 7 Shaukat A, Kahi CJ,

[7] Burke CA, Rabeneck L, Sauer BG, Rex DK. ACG Clinical Guidelines: Colorectal Cancer Screening 2021. Am J Gastroenterol. 2021;116(3):458-479. doi: 1014309/ajg.0000000000001122. PMID: 33657038

[8] L Hol, , J A Wilschut, M van Ballegooijen,A J van Vuuren, H van der Valk, J C I Y Reijerink, A C M van der Togt, E J Kuipers, J D F Habbema, and M E van Leerdam, Screening for colorectal cancer: random comparison of guaiac and immunochemical faecal occult blood testing at different cut-off levels Published online 2009 Mar 31. doi: 10.1038/sj.bjc.6604961

[9] Sobin M, Gospodarowicz L, Wittekind C. (eds). International Union Against Cancer. TNMClassification of Malignant Tumours, 7th Edition. Chichester: Wiley-Blackwell; 2009

[10] Colorectal Cancer Stages (www.e-cancer.fr, last visited November 25, 2013)

[11] Van Rossum LG, van Rijn AF, Laheij RJ, van Oijen MG, Fockens P, Jansen JB et al. Cutoff value determines the performance of a semi-quantitative immunochemical faecal occult blood test in a colorectal cancer screening programme. Br J Cancer 2009;101(8):1274-81.

[12] Segnan N, Patrnick J, von Karsa L. European guidelines for quality assurance in colorectal cancer screening and diagnosis. 1st. Luxembourg: Office for Official Publications of the European Communities. 2010;1-386.

[13] Canadian Partnership Against Cancer. Data definition and calculations instructions to measure quality indicators in CRC screening in Canada. 2012. Unpublished document.

[14] Major D. Targers and indicators workshop. Paper presented at the Canadian Partnership Against Cancer Conference: CRC Screening, Monitoring Program Performance. St. John's, Newfoundland and Labrador. 2011.

[15] Corley DA, Jensen CD, Quinn VP, Doubeni CA, Zauber AG, Lee JK, Schottinger JE, Marks AR, Zhao WK, Ghai NR, Lee AT, Contreras R, Quesenberry CP, Fireman BH, Levin TR Association Between Time to Colonoscopy After a Positive Fecal Test Result and Risk of Colorectal Cancer and Cancer Stage at Diagnosis JAMA. 2017 Apr 25;317(16):1631-1641

Stability and Adaptation of Soya Strains Based on different Models in the North and Northeast Regions

Guilherme Raposo Teixeira[1], Luiz Henrique de Freitas Barbosa[2], Angelo Ricardo Balduino[3], Luan Henrique Guarido da Silva[4]

[1]Department of Agronomy, Tocantnense Institute President Antonio Carlos, Brazil
Email: raposo.agro@hotmail.com
[2]Department of Agronomy, Tocantnense Institute President Antonio Carlos, Brazil
[3]Department of Agronomy, Tocantnense Institute President Antonio Carlos, Brazil
[4]Department of Agronomy, Soy Genetics, Brazil

Abstract— In Brazil, soya is the most important annual crop and is grown in a variety of environmental conditions. The environmental effect segregates the growing regions, where each one has its own peculiarities, and it is therefore the responsibility of genetic improvement programmes to meet the demand for new cultivars that overcome the instabilities and take advantage of the beneficial conditions of these environments. The aim of this study was to assess the productivity, adaptation and stability of soya strains in VCU trials. A randomised block design with three replications was used, in which six strains and two commercial cultivars were part of the trials in the cities of Cariri-TO, Caseara-TO, Aparecida do Rio Negro-TO, Porto Nacional-TO, Balsas-MA and Barreiras-BA, in the 2022/23 harvest. The REML/BLUP variational modelling method was used to analyse the data, estimate genetic parameters and predict genotypic values via MHPRVG. Significance was observed for genotypic effects and double interaction. The average heritability was adequate for the type of data set, which showed high accuracy. The genotype x location interaction showed a high coefficient of determination and the opposite was observed for the correlation, demonstrating the great influence of this effect on the results, thus highlighting its importance for the study, according to genetic parameters estimated via various models. According to the BLUPs for MHPRVG, the SOY 03 strain showed the best behaviour compared to the others and could be used as a cultivar.

I. INTRODUCTION

The soya bean, Glycine max (L.) Merrill, is an annual plant grown worldwide to produce oil and protein. Originally from the north-eastern Chinese region, it belongs to the Fabaceae family, where it has been cultivated for millennia. In this region, there are estimates that indicate that the plant has been used for human and animal consumption for more than 5,500 years and is considered by local traditions to be one of the five sacred grains (SEDIYAMA, 2016).

Originally from a temperate climate, it has been widely adapted to subtropical and tropical regions, showing obvious plasticity, which has led to research into its behaviour in a wide range of fields of study, especially plant breeding (SEDIYAMA, 2016).

In Brazil, the first reports of its introduction and cultivation date back to 1882, in Bahia, for fodder use.

However, in this region the crop was unsuccessful because the cultivars came from the United States and did not adapt to the conditions. Later, in 1891, it was cultivated in São Paulo to produce food grains, and in 1914 in Rio Grande do Sul, with the aim of research. In both cases, the adaptation was superior to the first cultivation in Brazil, however, the best performance was obtained in the state of Rio Grande do Sul, as it had environmental conditions similar to the northern United States, where the cultivars originated (MIYASAKA; MEDINA, 1981).

Brazil is currently the largest exporter and producer of this oleaginous crop. In the 2023/2024 harvest, the forecast is that Brazil will harvest a total of approximately 162.003 million tonnes, in a territory of more or less 45.182 million hectares, with an average yield of 3586 kg ha-1 (CASTRO, 2019; CONAB, 2023).

In this context, private and public genetic improvement programmes are largely responsible for this extraordinary advance in cultivation. Currently, this commodity is grown from north to south in the country, showing wide adaptation (CRUZ et al., 2012).

The aim of the following study was to assess the productivity, adaptation and stability of soya strains in the face of local variations and to identify promising strains for generating cultivars.

THEORETICAL REFERENCE

According to Cruz et al. (2012), for soya and many other crops, the main basis of genetic improvement programmes is the wide genetic variability contained in their segregating populations, which will give rise to future cultivars. This genetic variability is of great importance, as it allows for the selection of a wide range of traits, whether they be productivity, phenological or linked to biotic and abiotic factors. Among these traits, many are of quantitative inheritance and therefore of low heritability, showing complex behaviour and being highly influenced by the environment.

In addition to gathering all the desirable traits, genetic improvement programmes must meet market demands, which are not constant and change over the course of the harvest. In this way, there are cases in which productive cultivars are not necessarily successful cultivars, sometimes because they have characteristics that do not please producers and end consumers, so the breeder must be the bridge between research and the development and commercialisation of products, being aware of market trends (SEDIYAMA, 2016).

Because it is grown in a wide range of regions, one of the major challenges is separating genotypes, due to the presence of complex interactions between the environment and the genotype. Understanding this phenomenon is essential for breeders to be able to make more assertive selections for the most diverse growing locations (MAIA et al., 2006).

Breeding programmes have been looking for strategies to carry out more reliable analyses of phenotypic and genomic data, thereby increasing the efficiency of genotype separation. Each year, new procedures and more robust methodologies are adopted to make this process more reliable and improve recommendations (PIMENTEL et al., 2014).

Similar to other crops, phenotypic variations are not constant over a wide range of environments, mainly due to frequent climate changes. This means that, today, most recommendations are for smaller and smaller regions. It is therefore essential to differentiate the types of cultivars with predictable behaviour that can be responsive to environmental changes (CRUZ et al., 2012).

Through Crop Value and Use (VCU) trials, one of the final stages of soybean genetic improvement, data is obtained that allows us to observe the behaviour of strains according to their productivity, adaptation and stability. For this type of analysis, the methodology using mixed models or REML/BLUP (Restricted Maximum Likelihood / Best Linear Unbiased Prediction) offers accurate predictions (RESENDE, 2006; SOARES et al., 2015).

This analysis consists of the following assumptions: the lower the standard deviation of genotypic behaviour across environments, the higher the harmonic mean of their genotypic values in these environments (Resende, 2006). Therefore, when selecting for the highest MHVG values, the breeder will separate for production and stability (CASTRO, 2019).

When this selection is made, it refers to the ability of genotypes to show highly predictable behaviour in the face of unfavourable environmental variations (CRUZ et al., 2012).

Adaptation refers to the relative performance of genotypic values (PRVG) across environments. In this bias, the predicted genotypic values are expressed as a proportion of the general average of each environment, then the average value of this proportion across these environments is obtained. This adaptability is related to the ability of genotypes to take advantage of environmental variations, resulting in good yields. Adaptation efficiency depends on a series of influences and interactions (RESENDE, 2016).

Simultaneous separation by productivity, stability and adaptation, on the other hand, is carried out using the harmonic mean of the relative performance of genotypic

values (MHPRVG) method, which makes it possible to select simultaneously for MHVG and PRVG attributes (RESENDE, 2006; CASTRO, 2019).

According to Resende (2004), Regitano Neto et al. (2013) and Soares et al. (2015), in their studies with other methodologies such as Lin and Binns (1988) and Annicchiarico (1992), they generally provide values similar to those of mixed model analyses. However, the MHPRVG, given that it is estimated by BLUP, offers results on the same scale of character evaluation and presents genotypic and non-phenotypic effects to select stable genotypes that are responsive to the improvement of each environment.

For Stefanova and Buirchell (2010), when considering that the aim of the analysis is to select the best performing genotypes based on their classification, assuming the effects of genotypes as random types and the consequent use of BLUPs is justified, as these maximise the correlation between the estimates obtained for the values of the random effects and the true planting and use values of the strains tested.

Furthermore, according to Resende (2007), assuming the heritability value of the character to be equal to 1 (an implicit assumption when considering the effects of genotypes as fixed and without effects weighted by reducing factors) is unrealistic within genetic improvement, especially for characters such as grain yield.

Therefore, no studies were found in the literature using mixed models to assess the productivity, adaptation and stability of soya strains in different locations and years. However, given its advantages, as well as its use in various allogamous species, this methodology has been widely used in some autogamous crops such as common bean (Carvalho, 2015) and rice (Borges et al., 2010; Colombari Filho et al., 2011; Regitano Neto et al., 2013). This highlights the relevance of this study and the use of this type of approach in soya strains.

II. METHODOLOGY

The test was carried out in the 2022/23 agricultural year in the cities of Cariri-TO, Caseara-TO, Aparecida do Rio Negro-TO, Porto Nacional-TO, Balsas-MA and Barreiras-BA (Table 1). Using the results related to the Crop Value and Use (VCU) trials for 06 experimental lines, all of which have Intacta RR2 PRO® technology.

The strains used come from the Soybean Genetic Improvement Programme developed by Genética SOY and two commercial cultivars that are widely accepted in the region of the experiments were also used (Table 2), resulting in 08 treatments. At the request of the

transferring company, the strains were coded for presentation in this work.

Table 1: Characteristics of the sites used in the state of Mato Grosso do Sul in the trials.

Order	Municipality	REC*	Altitude(m)
1	Caseara -TO	501	206
2	Balsas -MA	501	507
3	Cariri -TO	404	293
4	Aparecida do Rio Negro -TO	501	370
5	Santa Rosa do Tocantins -TO	404	284
6	Porto Nacional -TO	501	244
7	Barreiras -BA	405	820

*Edaphoclimat micro – region.

Table 2: Characteristics of the genotypes and commercial cultivars evaluated.

Table 2. Characteristics of the genotypes and commercial cultivars evaluated.

Order	Treatment	G.M.*
1	SOY 01	7.5
2	SOY AMPLA IPRO	7.9
3	SOY 02	7.9
4	SOY 03	7.9
5	SOY 04	7.9
6	SOY 05	7.8
7	SOY 06	8.2
8	BMX Olimpo IPRO	8.0

*Relative maturity group

The experiments were set up using a randomised block design (RBL) with three replications. The plots were made up of four rows of plants five metres long, with row spacing of 0.50 metres. For evaluation purposes, only the two centre rows were harvested, totalling a useful area of 5 m² per plot.

The crop was harvested using a plot harvester, after which it was cleaned to remove impurities. Subsequently, the grains were subjected to moisture determination and weighed on a digital scale, the moisture was converted to 13% and the yield results were transformed into kg ha-1 in order to carry out the analyses.

These were carried out via mixed modelling, using model 54 of the Selegen REML/BLUP software, which includes a complete block design with several locations and one observation per plot - the MHPRVG method, as described by RESENDE (2006).

Using the mathematical-statistical model: y= Xr+Zg+Wi+e, the variance component estimates were calculated using the restrictive maximum likelihood (REML) method and the necessary genetic parameters were obtained from these values. Genotypic values were predicted using the best linear unbiased prediction (BLUP).

According to Resende (2006), BLUP's make it possible to identify genotypes with high stability and productivity, which is measured by the harmonic mean of genotypic values (MHVG), adaptation and productivity are obtained through the relative performance of genotypic values (PRVG) and simultaneous selection for productivity, adaptation and stability is achieved by the Harmonic Mean

of Relative Performance of Genotypic Values (MHPRVG) (RESENDE, 2006).

The MHPRVG indications that were used for selection correspond to:

$$MHPRVG_i = \frac{n}{\sum_{j=1}^{n} \frac{1}{Vg_{ij}}}$$

Source: Formula in Carvalho, Silva, Resende (2017).

where, n is the number of locations where genotype i was evaluated, Vgij is the genotypic value of genotype i in environment j, expressed as a proportion of the mean of that environment (RESENDE, 2016).

III.   RESULTS AND DISCUSSION

Table 3 shows the deviance table (ANADEV) for the complete model and without the effects of genotype (g), genotype x location interaction (gl), as well as the likelihood ratio test (LRT) for their respective effects.

Table 3: Deviance Analysis (ANADEV) and Likelihood Ratio Test (LRT) for genotype and genotype x location effects for the yield trait in seven locations in the North and Northeast regions.

Table 3. Analysis of Deviance (ANADEV) and Likelihood Ratio Test (LRT) for genotype and genotype x location effects for the yield character in seven locations in the North and Northeast regions.

Effects	Deviances	LRT ( )x^2
Genotype (g)	2004,23+	4,75*
Genotypes x locations (gl)	2006,53+	7,05**
Complete Model	1999,48	-

* Deviance of the adjusted model without the corresponding effects.
* relative to a probability of 1% using the chi-squared test, with 1 degree of freedom.
** significant at 5% probability by the chi-squared test, with 1 degree of freedom.

According to the chi-squared test applied to the LRT, the genotype effect was significant at 1%, i.e. the genotypes differed statistically for the grain yield character. This means that there is genetic variability between the lines, thus favouring selection.

The effects of the double gl interaction were significant at 5%. According to Colombari Filho (2011) and Regitano Neto et al. (2013), in their studies with rice lines, the possible explanation for this behaviour in the results for the double interaction is that the variations in conditions that occurred between locations reflected a significant change in the behaviour of the genotypes studied.

Another probable explanation for the significance of this effect is that the environments are in different regions and have particular soil and climate conditions.

The overall average yield was approximately 3755.97 kg ha-1. Table 4 shows the estimates of the variance components: genotypic (Vg), genotype x location interaction (Vint), residual (Ve) and phenotypic (Vf). Also shown are the genetic parameters of average heritability of the genotypic effects of the lines (h2g), selective accuracy

(Acgen), experimental coefficient of variation (CVe), coefficients of determination of the effects of the genotype x location interaction (c2int), as well as the genotypic correlation between performance in the various environments (rgloc), during the 2022/23 harvest.

Table 4: Estimates of variance and genetic parameters for the effects studied for the yield character in four locations and two harvests in the soya crop.

Table 4: Estimates of variance and genetic parameters for the effects studied for the yield character in four locations and two harvests in the soya crop.

Effects	Variances (V)	Coefficients (%)	Correlations (r)
Genotype (g)	V_g = 35435.94	h^2_g = 12,78	
Genotypes x locations (gl)	V_{int} = 58541.26	c^2_{int} = 21,11	r_{gloc} = 0,377
Waste	V_e = 183296.61		
Complete model	V_f = 277273.82	CV_e = 11,39	A_{cgen} = 82,13

The experimental coefficient of variation (CVe) was 11.39%, considered to be at an adequate level (RESENDE, 2004), demonstrating good experimental precision. However, it only depends on the residual variation as a proportion of the experiment mean, and in order to better assess the reliability of the data, genotype evaluation trials should be approached from a genetic and statistical point of view, and not just from a statistical perspective, i.e. validated in terms of experimental quality and precision.

Resende and Duarte (2007) and Henderson (1984) argue that one of the most relevant parameters for assessing the quality of an experiment via genotypic evaluation is accuracy. This parameter refers to both the genuine genotypic value for the genetic treatment and the value approximated using the data from the experiments.

According to Resende and Duarte (2007), analyses in different environments are essential for breeding programmes in order to select superior genotypes and subsequently generate improved cultivars. In these experiments, it is desirable to have high experimental precision and, consequently, accurate inference about the genotypic means, i.e. the genotypic values of the genetic treatments being evaluated.

Experimental quality measured by accuracy reflects the effectiveness of inferring genotypic values, i.e. predicting values via BLUP (BORGES et al., 2009). In this study, the Acgen obtained was 82.13%. This value is classified as high, demonstrating that the predictions made can be considered highly reliable, providing breeders with assertive selections (RESENDE; DUARTE, 2007).

According to Falconer (1981), heritability is the fraction of phenotypic variance equivalent to genetic origin. As can be seen, the average heritability of the strains (h2g) was 12.78%, a result considered to be of low magnitude. According to Candido (2016), this result is explained by the fact that productivity is a polygenic

quantitative character and is therefore strongly influenced by the environment, which in the case of this study was strongly influenced by variations between different locations.

The coefficient of determination c2int indicates how much each interaction component contributes to the phenotypic variance (Borges et al., 2010). The coefficients for the effects of the double interaction c2int contributed 21.11%, and were considered significant for the test levels estimated for each effect. These results mean that the phenotype of the strains contributed to the effects evaluated, i.e. there were statistically significant differences in the local stratum when analysed independently. These results are complementary to those observed in the variances in Table 4.

The rgloc genotypic correlation estimates were of low magnitude (0.377), which was to be expected because if the coefficients of determination for these double interactions were high, it was probably because the behaviour of the genotypes across the sites varied so much.

These correlation values from this analysis reflect nothing more than the coincidence between the behaviour of the genotypes across each effect analysed (Resende, 2006). According to Torres et al. (2015), the genotypic correlations of the performance of genetic materials, across locations, provide the reliability of how constant the "ranking" of the genotypes is across the environments tested, thus, as discussed above, it is once again evident that genotype x location interactions are generally complex and significant interactions.

In order to demonstrate the behaviour not only of the data set in the environment evaluated (locations) but also of each genotype evaluated in the VCU trial, it is important to analyse the individual results of the average of each strain. This is best done by analysing adaptation and stability studies.

Table 5 shows the (MHVG), which refers to the Harmonic Mean of Genotypic Values, which indicates the predictions for stability and productivity of genetic values, relative performance of genotypic values (PRVG) which indicates the predictions for adaptability and productivity of genetic values, as well as the overall mean (PRVG*MG) and the harmonic mean of the relative performance of genotypic values (MHPRVG) which are the predictions for stability, adaptation and productivity of genetic values and also at the level of the overall mean (MHPRVG*MG) for the grain yield kg ha-1 trait, in a joint analysis of four locations over two years.

*Table 5: Stability and productivity of genotypic values (MHVG), adaptability and productivity of genotypic values (PRVG), (PRVG*MG), stability, adaptability and*

*productivity of genotypic values (MHPRVG), (MHPRVG*MG) for the productivity character grain yield kg ha-1 in seven municipalities in the north and northeast of Brazil for soya.*

Table 5 Stability and productivity of genotypic values (MHVG), adaptability and productivity of genotypic values (PRVG), (PRVG*MG), stability, adaptability and productivity of genotypic values (MHPRVG), (MHPRVG*MG) for the character grain yield kg ha^{-1} , in seven municipalities in the north and northeast of the country in soya cultivation.

Ord	Treatment	MHVG	PRVG	PRVG*MG	MHPRVG	MHPRVG*MG
1	SOY 03	3.979	1,081	4.061	1,081	4.058
2	BMX Olimpo IPRO	3.891	1,058	3.975	1,058	3.972
3	SOY AMPLA IPRO	3.696	1,006	3.777	1,004	3.772
4	SOY 02	3.676	1,007	3.782	1,004	3.770
5	SOY 04	3.668	1,001	3.759	0,995	3.737
6	SOY 01	3.562	0,970	3.642	0,969	3.640
7	SOY 06	3.492	0,955	3.587	0,954	3.584
8	SOY 05	3.377	0,923	3.466	0,921	3.460

Methodologies based on regression or multiplicative models AMMI and GGE Biplot show limitations in dealing with unbalanced data as well as the heterogeneity of variances between the environments analysed and these methods assume the genotypic effects are fixed, which is inconsistent when you want to predict variance components and parameters. The mixed model method is therefore more appropriate, as it assumes the effects of genotypes to be random, which makes it possible to obtain BLUPs as predictors of line behaviour (RESENDE, 2007).

Stability is verified according to the MHVG, which penalises the instability of genotypes when analysed in different environments. Furthermore, when the genotype shows negative behaviour in the face of adversity in the environments analysed, its stability is deflated (RESENDE, 2007). Instability due to climate and soil dissimilarity require the cultivars indicated to present a balance between productivity and stability (CRUZ et al., 2012).

Adaptation, verified by means of PRVG, is the ability of genotypes to respond in an advantageous way to variations in the environment when it increases productivity. Thus, adaptation is capitalised when the genotype responds positively to favourable situations (RESENDE, 2007).

The same ranking was observed (Table 5) for the treatments used according to MHVG, PRVG*MG, and then for simultaneous selection in MHPRVG*MG. In this case, the stable and productive lines showed similar levels of adaptation and productivity and for simultaneous selection, with the exception of the BMX Olimpo IPRO, SOY Ampla IPRO and SOY 02 treatments, which reversed their positions.

Of particular note is the SOY 03 strain, which has the highest BLUP or MHPRVG value. It is important to emphasise that this strain was superior to the commercial cultivars BMX Olimpo IPRO and SOY Ampla IPRO,

which are standouts for the locations evaluated. We can see that the genotype he obtained predicted MHPRVG about 2.3 per cent higher than the runner-up (BMX Olimpo IPRO). Therefore, according to the VCU trials evaluated, this is the most stable, adaptable and productive strain, with great potential as a cultivar.

According to Cruz and Carneiro (2006), the use of cultivars with broad adaptability and good stability is one of the options for reducing the influence of the G x A interaction, as the analyses provide detailed information on the behaviour of each genotype in the face of the most diverse environmental variations, and are therefore of great importance for genetic improvement programmes.

IV. CONCLUSION

The SOY 03 soya strain showed wide adaptation, stability and productivity, demonstrating higher predictions of genotypic values from varied models than commercial cultivars, and is therefore promising for use as a commercial cultivar in environments with similar characteristics to those studied.

Analyses involving genotype x location interaction are of great importance for studying the behaviour of lines in VCU trials, according to genetic parameters estimated from varied models.

REFERENCES

[1] ANNICCHIARICO, P. Cultivar adaptation and recommendation from alfalfa trials in northern Italy. Journal of Genetics and Plant Breeding, v.46, n. 3, p. 269-278, 1992.

[2] BORGES, V.; SOARES, A. A.; RESENDE, M. D. V.; REIS, M. S.; CORNÉLIO, V. M. O.; SOARES, P. C. Genetic progress of the Minas Gerais highland rice improvement programme using mixed models. Revista Brasileira de Biometria, Lavras, v. 27, n. 3, p. 478-490, 2009.

[3] BORGES, V.; SOARES, A. A.; REIS, M. S.; RESENDE, M. D. V.; CORNÉLIO, V. M. O.; LEITE, N. A.; VIEIRA, A. R. Genotypic performance of upland rice lines using mixed modelling methodology. Bragantia, Campinas, v. 69, n. 4, p. 833-841, 2010.

[4] CANDIDO, W.S. Selection indices and stability and adaptability in head lettuce lines via REML/BLUP. 2016. 99f. Thesis (Doctorate in Genetics and Plant Breeding). - Unesp, Jaboticabal, 2016.

[5] CASTRO, D. O. C. Adaptability and stability of Libertylink soya genotypes by Relm/Blup. Master's thesis. University of Brasília. 2019. Available at: https://repositorio.unb.br/bitstream/10482/37515/1/2019_Da niloOliveiradeCastro.pdf Accessed on: 20 October 2023.

[6] CARVALHO, L.C.B. Interpretation of the genotypes x environments interaction in cowpea using multivariate, mixed models and environmental covariates. 2015. 115f. Thesis (Doctorate in Genetics and Plant Breeding). - Luiz de Queiroz College of Agriculture, Piracicaba, 2015.

[7] COLOMBARI FILHO, J. M.; CASTRO, A. P.; BRESEGHELLO, F.; MORAIS, O. P. Genotypic evaluation of upland rice lines using mixed models for the state of Mato Grosso. In: Anais 6° CONGRESSO BRASILEIRO DE MELHORAMENTO DE PLANTAS, Búzios: SBMP, 2011.

[8] CONAB. Monitoring the Brazilian Harvest. 2023. Available at:<www.conab.gov.br>. Accessed on 20 October 2023.

[9] CRUZ, C. D.; CARNEIRO, P. C. S. Biometric models applied to genetic improvement. Viçosa: UFV, 2006.

[10] CRUZ, C. D.; REGAZZI, A. J.; CARNEIRO, P. S. Modelos biométricos aplicados ao melhoramento genético, 4 ed.

[11] FALCONER, D.S. Introduction to Quantitative Genetics. Viçosa: UFV. 1981. 279 p.

[12] HENDERSON, C.R. Aplications of linear models in animal breeding (Aplicações de modelos lineares na criação de animais). Guelph: Universidade de Guelph. 1984. 462 p.

[13] LIN, C. S.; BINNS, M. R. A superiority measure of cultivar performance for cultivar x location data. Canadian Journal of Plant Science, v. 68, n. 1, p. 193-198, 1988.

[14] MAIA, M.C.C.; VELLO, N.A.; ROCHA, M.M.; PINHEIRO, J.B.; SILVA, N.F. Adaptability and stability of experimental soya strains selected for agronomic characters using a uni-multivariate method. Bragantia, Campinas, v. 65, n. 2, p. 215-226, 2006.

[15] MIYASAKA, S.; MEDINA, J.C. Soya in Brazil. Campinas: Instituto de tecnologia de alimentos-ITAL, 1981. 1061 p.

[16] MORETO, A. L.; NEUBERT, E. O.; PERUCH, L. A. M.; POLA, A. C.; LORENZI, E F. P. de; NUNES, E. C. Performance of cassava genotypes via mixed modelling methodology in Santa Catarina, Brazil. Revista de Ciências Agrárias, 2017, 40(4): 830-838. Available at: https://revistas.rcaap.pt/rca/article/view/16528 Accessed on: 22 October 2023.

[17] PIMENTEL, A. J. B.; GUIMARÃES, J. F. R.; DE SOUZA, M. A.; DE RESENDE, M. D. V.; MOURA, L. M.; RIBEIRO, G. Estimation of genetic parameters and prediction of additive genetic value of wheat using mixed models. EMBRAPA, Brasília, v. 49, n. 11, p. 882-890, 2014.

[18] REGITANO NETO, A.; JUNIOR-RAMOS, E.U.; GALLO, P.B.; FREITAS, J.G.; AZZINI, L.E. Behaviour of upland rice genotypes in the state of São Paulo. Revista Ciência Agronômica: Fortaleza, v. 44, n. 3, p. 512-519, 2013.

[19] RESENDE, M.D.V. Optimal statistical methods for analysing field experiments. Colombo: Embrapa Florestas, 2004. 65p.

[20] RESENDE, M.D.V. Manual Software Selegen-REML/BLUP. Campo Grande: EMBRAPA, 2006. 305p.

[21] RESENDE, M.D.V. Mathematics and statistics in the analysis of experiments and in genetic improvement. Colombo: Embrapa Florestas, 2007. 435 p.

[22] RESENDE, M. D. V. Software Selegen-REML/BLUP: uma ferramenta útil para o melhoramento de plantas. Melhoramento genético de culturas e biotecnologia aplicada, Viçosa, v. 16, n. 4, p. 330-339, 2016.

[23] RESENDE, M.D.V.; DUARTE, J.B. Precision and quality control in cultivar evaluation experiments. Pesquisa Agropecuária Tropical, Goiânia, v. 37, n. 1, p. 182-194, 2007.

[24] SEDIYAMA, T. Soya Productivity. Londrina: Macenas, 2016. 310p.

[25] SOARES, A. A.; REIS, M. S. R.; CORNELIO, V. M. O.; LEITE, N. A.; SANTOS, V. B.; RESENDE, M. D. V.; SOARES, P. C. Stability and adaptability of upland rice cultivars and lines, estimated by a mixed model. Available at:
https://ainfo.cnptia.embrapa.br/digital/bitstream/item/13255 1/1/2009-Resende-EstabilidadeAdaptabilidade.pdf Accessed on: 03 November 2023.

[26] SOARES, A. A.; REIS, M. S. R.; CORNELIO, V. M. O.; LEITE, N. A.; SANTOS, V. B.; RESENDE, M. D. V.; SOARES, P. C. Genotypic performance of upland rice lines using mixed modelling methodology. Available at: https://www.scielo.br/j/brag/a/Bgn6QvKqDdxjmz43pyLrcrP # Accessed on: 03 November 2023.

[27] STEFANOVA, K.; BUIRCHELL, B. Multiplicative mixed models for evaluating genetic gain in lupin improvement. Crop Science, Madison, v. 50, n. 3, p. 880-891, 2010.

[28] TORRES, F. E.; TEODORO, P. E.; SAGRILO, E.; CECCON, G.; CORREA, A. M. Genotype x environment interaction in semiprostrate cowpea genotypes via mixed modelling. Bragantia, Campinas, v. 74, n. 3, p. 255-260, 2015.

The use of Bamboo in construction: a sustainable alternative

O uso do Bambu na construção civil: uma alternativa sustentável

Cleysson Márcio Guimarães da Cunha, Priscila Alves da Silva Machado

Universidade do Estado de Minas Gerais - Unidade João Monlevade

Abstract— The civil construction sector, responsible for the movement of billions of reais, demonstrates a substantial economic impact in Brazil. However, this impact is accompanied by the high consumption of natural resources and the generation of waste. Faced with growing environmental awareness and the need to reduce impacts arising from this nature, interest in sustainable alternatives arises, with emphasis on bamboo, due to its remarkable resistance, characteristics and rapid growth. This work proposes to investigate the perspectives of using bamboo in construction and identify strategies for its effective adoption, considering economic, sustainable and regulatory aspects.

I. INTRODUÇÃO

O setor da construção civil foi responsável por movimentar R$ 377,8 bilhões em 2021, sendo destes, 355,8 bilhões, aproximadamente, referentes a obras e/ou serviços, segundo o Instituto Brasileiro de Geografia e Estatística (IBGE), em 2023.

Considerando o impacto econômico significativo gerado pelo setor da construção civil em 2021, é plausível inferir que uma quantidade substancial de energia foi consumida na produção dos materiais necessários para as obras.Esse consumo energético assume particular importância quando se trata do uso intensivo de aço na construção civil. Agopyan e John (2011) afirmam que a construção civil é uma das indústrias que mais consomem recursos naturais e geram resíduos no mundo.

Atualmente, o interesse em soluções sustentáveis para vários setores industriais tem se intensificado, sobretudo

para o da construção civil, impulsionado pela crescente conscientização ambiental e a necessidade de reduzir o impacto negativo para o meio ambiente. Nesse contexto, o bambu emergiu como um material de construção promissor, destacando-se por sua notável resistência, versatilidade e, acima de tudo, sua capacidade decrescimento rápido e renovável, de acordo com Trevisan et al., (2019 apud Marques Luiz e Silva 2020), que advertem que o bambu não pode ser considerado 100%sustentável, pois demanda tratamentos para controle de pragas, podendo esses, ser de natureza física ou química.

No entanto, de acordo com Nunes e Junior (2021), o bambu desponta como uma solução para a construção sustentável devido à sua natureza não poluente e às propriedades comparáveis a outros materiais convencionais na construção civil, além de apresentar

baixo consumo de energia, o que o torna uma alternativa mais econômica.

É importante destacar que o Brasil ostenta uma variedade de mais de 240 espécies distintas dessa planta, destacando-se como líder em biodiversidade no continente americano. Porém, encontra-se em desvantagem em relação a várias nações com menos recursos naturais e avanços tecnológicos (Ribas, 2015).

De acordo com a pesquisa de Trevisan *et al.,* (2019 *apud* Marques Luiz e Silva 2020), o cultivo de bambu desempenha um papel significativo na redução do carbono na atmosfera. Isso ocorre devido à sua notável taxa de crescimento, que resulta na conversão de uma quantidade maior de dióxido de carbono em oxigênio, se comparado às árvores. Além disso, Fialho *et al.*, (2005 *apud* Drumond e Wiedman, 2017), destacam que seu uso pode ser uma excelente opção para comercialização em grande escala, uma vez que o bambu não necessita de replantio. Nesse sentido, apresenta grande potencial de geração de renda para produtores rurais. Em contraste, os materiais de construção convencionais como o concreto e aço, embora seja um pilar na construção convencional, levanta preocupações significativas relacionadas à emissão de gases de efeito estufa, provenientes de sua produção e ao esgotamento de recursos.

No cerne da transformação da construção civil está a busca incessante por alternativas sustentáveis. Estas, não apenas atendem às necessidades presentes, mas também asseguram um futuro responsável para as próximas gerações. Ademais, e não menos importante é a redução significativa do custo de construção de moradias, o que pode contribuir para mitigar o déficit habitacional, sendo esta, uma problemática presente em todas as regiões do país(Lima, 2020).

Dessa forma, a questão central que orienta esta pesquisa é: Quais perspectivas se apresentam para a utilização do bambu como material alternativo no setor da construção civil, e quais estratégias podem ser implementadas para enfrentar os desafios associados à sua adoção eficaz em projetos de construção, considerando aspectos econômicos, sustentáveis e regulatórios?

Este trabalho propõe um levantamento bibliográfico sobre o tema e análise de experimentos já realizados, afim de analisar a substituição de materiais de construção convencionais pelo bambu, o que pode contribuir para a sustentabilidade e trazer economia às famílias de baixa renda e/ou famílias residentes em áreas rurais onde já se dispõe dessa matéria prima de forma abundante, eliminando os gastos iniciais com compra e transporte, dessa. Além domais, contribuir para o diálogo em torno de uma construção civil mais consciente e harmoniosa com o meio ambiente e as necessidades de nossa sociedade.

II.   ESTUDO ARTE

2.1 Bambu

O bambu é uma planta gramínea, integrante da família *Poaceae* à subfamília *Bambusoide*, da classe *Monocotyledoneae*, divisão das *Angiospermeae* (Isaia, 2017).

Desse modo, Silva, G. A. (2020) e Silva, J. V. (2020) esclarecem que essa planta está presente constantemente no cenário brasileiro, em toda zona tropical e parte da zona subtropical do globo terrestre, possui crescimento rápido.

Pereira (2018) declara a existência de mais de 1.200 espécies de bambu distribuídas e catalogadas em, aproximadamente, 90 gêneros, espalhadas pelo mundo.

No Brasil, o bambu se divide em duas categorias distintas: lenhosos e herbáceos, sendo estes mais finos e flexíveis, ideais para aplicações em trabalhos de menor escala, como artesanato. Já os lenhosos, também chamados de guaduas, apresentam um tronco espesso e duro (Oliveira, 2013).

Ainda, de acordo com Andrade (2022), as variedades mais comuns no território brasileiro compreendem:

- *Bambusavulgaris*, (bambu verde);
- *Bambusavulgaris var. vitata,* (bambu imperial);
- *Bambusatuldoides*, (bambu comum);
- *Guadua angustifólia*;
- *Phyllostachys,*(algumas variantes);
- *Dendrocalamusgiganteus*, (bambu gigante ou bambu balde);

Isaia (2017) e Rusch, Hillig e Ceolin(2018) explicam que os principais componentes da macroestrutura do bambu são as raízes, rizomas, colmos, ramos, folhas e flores e frutos. A morfologia do bambu é mostrada na Fig 1.
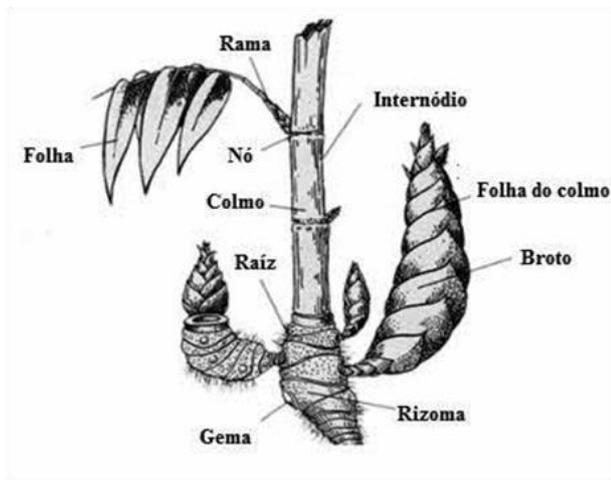
Fig.1: Anatomia da macroscopia do bambu.

Fonte: NMBA, (2004 apud Padován, 2010).

Isaia (2017) explica que os colmos, também conhecidos como hastes de bambu possuem uma composição fibrosa e dura, constituída principalmente por celulose e lignina. São tubos tronco-cônicos com saliências onde se situam os nós, sendo esses a estrutura principal da parte aérea da planta. Eles são, frequentemente, utilizados na construção em diversas aplicações. Na Fig. 2 é apresentado a seção de um colmo.
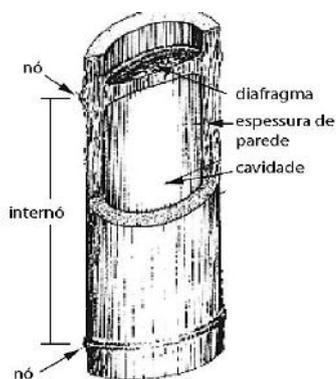
Fig.2: Colmo de bambu.

Fonte: Ghavami, Barbosa e Moreira (2017).

Para emprego na Engenharia, Ghavami, Barbosa e Moreira (2017) explicam que o comprimento médio dos colmos, a distância internodal (entrenó, interno ou internódio), o diâmetro externo e espessura da parede são parâmetros de suma importância de conhecimento, ao se optar por esse material. Além disso, os autores citam que tais parâmetros variam de acordo com a espécie, com fatores locais, como qualidade do solo, temperatura e umidade relativa do ambiente, insolação, espaçamento entre touceiras, com o manejo do bambuzal e devido a posição ao longo do colmo.

Devido à alta resistência mecânica e de tração, os colmos podem servir como viga, pilar, alvenaria, acabamento e várias outras funções (Souza, Leão e Quaresma, 2020).

Ghavami (2006) cita que os colmos são responsáveis por dar leveza e contribuir de forma importante para a flexibilidade. Aliado a essas qualidades, o bambu possui um baixo peso específico, o que reduz o custo de seu manuseio e transporte, comparado a outros materiais.

A camada externa do colmo, composta por feixes de fibras entrelaçadas, confere a ele grande parte de sua resistência e é fundamental para a durabilidade e estabilidade do material. Isso se deve à forma como a água é absorvida e distribuída dentro da planta, pois o tecido parenquimatoso decresce no sentido do centro para a parte externa o que promove maior densidade das fibras e como resultado, maior resistência (Almeida, 2023).

Apesar dos benefícios gerados pela resistência da parte mais externa dos colmos, sua estrutura anatômica dificulta o seu tratamento, principalmente os químicos, contra ataques de fungos e intempéries. Nesse sentido,Tiburtino *et al.,* (2015, p. 130) esclarece que "O bambu, ao contrário da madeira, não possui elementos anatômicos dispostos na direção radial, sendo os vasos o principal meio de movimentação dos líquidos no interior dos colmos".

No processo de absorção e liberação da água, as dimensões dos colmos do bambu podem ser alteradas (Ferreira, 2007). Em conformidade, o teor de umidade presente na gramínea pode afetar a estabilidade dimensional, resistência à flexão e à fluência.

Considerado um material compósito e anisotrópico quando analisado microscopicamente, o bambu é constituído por feixes de fibras aderidas a uma substância aglutinante, a lignina (Isaia, 2017).

Para a análise das propriedades, de acordo com Ghavami, Barbosa e Moreira (2017), é necessário adotar três direções: direção longitudinal, radial e circunferencial. Na Fig. 3 são apresentadas as direções a serem consideradas nos colmos de bambu.
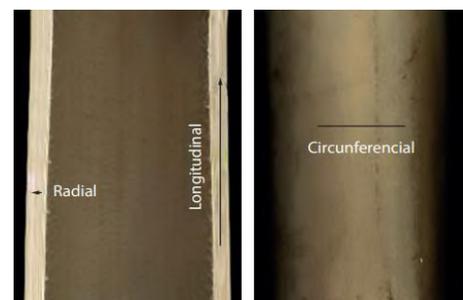
Fig.3: Direções a serem consideradas nos colmos de bambu.

Fonte: Ghavami, Barbosa e Moreira (2017).

Designada direção paralelas as fibras, a direção longitudinal é aquela analisada ao longo da espessura da parede do colmo. A direção circular ou circunferencial é aquela paralela ao perímetro da seção transversal do colmo e a radial é aquela que se analisa ao longo da espessura da parede do colmo (Isaia, 2017).

De acordo com Fabricio, Brito e Vittorino (2017), na direção radial as fibras presentes não são distribuídas homogeneamente na matriz, existe uma concentração delas próximo a face externa do material. Na direção radial é verificada a redução da presença de fibras à medida que se afasta da casca para o centro, mas toda via é identificada uma distribuição praticamente uniforme ao longo da direção longitudinal, como também na circunferencial (Isaia, 2017).

Embora o bambu seja um elemento esbelto, é um material muito resistente. Diante da distribuição das fibras e vasos não homogênea ao longo da espessura da parede, existe uma maior densidade, próximo à camada externa, o que eleva a resistência do colmo (Fabricio, Brito e Vittorino, 2017).

A resistência do colmo do bambu é instituída pela presença de vasos e veios formados por um tecido reforçado, denominado esclerênquima (Isaia, 2017).

1.2 Manejo

Com o intuito de prolongar sua vida útil, a obtenção do bambu requer alguns cuidados, deve-se destacar os principais pontos a serem analisados: a seleção, o corte, a cura, a secagem e os tratamentos imunizantes. A Associação Brasileira de Normas Técnicas (ABNT) por intermédio de sua normativa n° 17043 intitulada como "Varas de bambu para uso estrutural - Colheita, tratamento, preservativo e classificação pelo diâmetro", cita algumas premissas em relação ao uso de bambu como elemento estrutural.

2.2.1 Seleção

A seleção dos colmos para corte deve ser realizada apenas para os colmos maduros, com idade entre 4 e 7 anos. Além disso, a presença de galhos e subgalhos, pode evidenciar a idade do colmo, ao mesmo tempo, que colmos muito maduros, geralmente acima de 7 anos, apresentam-se secos e sem presença de galhos, esses devem ser desprezados (ABNT, 2023).

Para fins comerciais marcações devem ser feitas assim que os colmos despontarem nos bambuzais, com intuito de garantir sua maturidade (ABNT, 2023).

Os colmos selecionados devem não apenas estar visualmente maduros, mas também em bom estado de saúde, livres de quaisquer danos causados por fungos ou insetos, como perfurações. Além disso, não devem exibir quaisquer defeitos, como rachaduras e danos físico-mecânicos (ABNT, 2023).

2.2.2 Corte

A ABNT (2023) orienta o corte de colmos de bambu na plantação enfatizando a importância de evitar danos como fissuras e trincas. O corte deve ser realizado sem choques, rasando um nó na base do colmo para prevenir acúmulo de água. Recomenda-se o uso de motosserra ou equipamento equivalente, manejado por profissional qualificado e seguindo as instruções do fabricante. Outras ferramentas, como facões e machados podem ser utilizadas com precaução. Após a colheita, é necessário desbastar, retirar galhos e dividir o colmo em varas, preferencialmente de 3m ou 6m, sendo a serra tipo sabre um instrumento prático para essas operações.

Noia (2012) enfatizam que o melhor momento para cortar os colmos de bambus entouceirantes é durante a estação seca, quando a umidade e a quantidade de seiva são reduzidas. Isso diminui o risco de infestação por insetos xilófagos.

2.2.3 Cura

Logo após o corte, é essencial iniciar o processo de tratamento preservativo dos colmos. Uma abordagem tradicional envolve a cura/maturação na mata, visando preservar as propriedades naturais do bambu e prevenir a deterioração prematura do material. Consiste em posicionar os bambus verticalmente sobre uma pedra para permitir que a seiva residual escorra (ABNT, 2023).

De acordo com Noia (2012) essa etapa remove o amido e evita ataques de insetos por meio de um processo de fermentação que dura aproximadamente três semanas.

Outro processo indicado para a cura é a imersão em água: esta penetra no interior dos colmos, expulsando a seiva e requer um tempo mínimo de 3 semanas.

2.2.4 Secagem

A secagem do colmo de bambu é essencial para equilibrar sua umidade com a atmosfera. A ABNT (2023) ressalta que a após a secagem, a umidade se aproxima de percentuais que variam de 12% a 16%, de acordo com as características ambientais do local. Devem ser descartados colmos que apresentem fissuras que ultrapassem 2 nós em sequência ou que a soma de seus comprimentos seja igual ou maior que 20% do comprimento total da peça.

A secagem pode ser realizada por meios naturais, secagem ao ar livre, ou por processos controlados, como estufas (Almeida, 2016).

2.2.5 Tratamentos imunizantes

Segundo a norma supracitada, o tipo de tratamento preservativo, depende do tipo de utilização do colmo: interior ou exterior, além da legislação vigente, grau de toxicidade e segurança do manuseio. Esses tratamentos podem ser químicos ou naturais, sem ou sob pressão, dos quais cita os principais:

2.2.5.1 *Produtos hidrossolúveis*

Os produtos hidrossolúveis se dissolvem em água e protegem as varas de bambu, penetrando nos tecidos. (Pereira, 2018). A solução de tratamento pode ser reaproveitada, mas é essencial verificar sua limpeza e concentração antes de cada aplicação para assegurar a eficácia. A eficiência da solução reutilizada é mantida com concentração dos produtos hidrossolúveis e baixa matéria orgânica na água, podendo ser melhorada com processos de filtragem.

Um tratamento comum é a submersão das varas em uma solução de produtos químicos contendo boro. Exemplos incluem a combinação de ácido bórico e bórax, cada um em 3% a 4% (totalizando 6% a 8% da solução), ou octoborato de sódio, com pelo menos 5% em massa (ABNT, 2023).

2.2.5.2 *Óleos solúveis*

São usados solventes para diluir o material imunizante e facilitar a absorção pelos tecidos dos colmos, existem vários tipos de óleos solúveis utilizados no tratamento da madeira, mas esses são mais nocivos ao meio ambiente (ABNT, 2023).

2.2.5.3 *Tratamento natural: cura na mata ou imersão em água*

A ABNT (2023) ressalva que esses tratamentos não apresentam comprovação de proteção dos colmos a longo prazo. Desse modo recomenda sua utilização em construções simples e/ou temporárias.

2.2.5.4 *Imersão em soluções preservativas*

Os colmos são submersos em recipientes contendo uma solução. Eles devem ter perfurações na região dos diafragmas, feitas com uma broca de diâmetro mínimo de 12,5 mm e máximo de 16,0 mm, ou em forma de cruz com dois furos em cada junta dos nós. As perfurações devem ser inclinadas para evitar a continuidade na direção longitudinal das fibras e feitas com uma broca que não ultrapasse os 6,3 mm de diâmetro (ABNT, 2023).

2.2.5.5 *Injeção de solução nos entrenós*

De acordo com a ABNT (2023), é realizado um furo em cada entrenó com broca de 5mm e injetada uma solução preservativa, que dependendo do volume da cavidade internodal pode variar de 50 mL a 200mL

2.2.5.6 *Difusão vertical*

As varas de bambu são posicionadas na vertical com todos os diafragmas perfurados, exceto o último da base. Em seguida o tubo é preenchido com a solução preservativa. Em conformidade a norma apresentada, esclarece que dependendo da solução, esse tratamento pode durar duas semanas e que a solução pode ser reaproveitada (ABNT, 2023).

2.2.5.7 *Deslocamento da seiva*

Método conhecido como *Boucherie* modificado. Nele, um equipamento com mangueiras contendo o líquido imunizante é posicionado com bicos na extremidade do bambu (Marçal, 2008). Isso gera pressão, expelindo a seiva, que é então substituída pela solução. Esse processo é similar ao processo de autoclave, a diferença se dá pelo fato de os diafragmas serem perfurados, pois uma vez que são ocos, podem sofrer danos causados pelo processo de vácuo iniciado antes da aplicação da pressão (ABNT, 2023).

2.3 Propriedades físicas do bambu

De acordo com Marques, Luiz e Silva (2020), o tipo da espécie, técnicas de manejo e os fatores locais como: qualidade do solo, temperatura, umidade relativa do ambiente, topografia, espaçamento entre touceiras e regime pluvial, interfere de forma direta nas propriedades físicas do bambu. As principais propriedades que devem ser analisadas para a engenharia são: o comprimento do colmo, a distância entre os nós, o diâmetro, a espessura da parede, a absorção de água e a massa específica.

2.3.1 Comprimento do colmo

Algumas espécies de bambu podem superar os 30m de comprimento, o que promove a elas boas características físico-mecânicas, aliadas ao comprimento das fibras (Almeida, 2023). O encurvamento máximo do colmo é dado por: comprimento dividido por 100, ou seja, se o comprimento total é de 3 metros, seu encurvamento não pode ultrapassar 3cm (ABNT, 2023).

2.3.2 Distância entre nós

No nó, as fibras que anteriormente seguiam uma direção paralela se entrelaçam, resultando em uma maior densidade de fibras em várias direções. Isso confere ao nó uma maior capacidade de resistir à compressão e evita a separação das fibras ao longo dos entrenós. (Marçal, 2008). Nesse sentido a distância entre nós interfere nos valores de resistência: a medida que o espaçamento cresce a resistência à compressão tende a diminuir.

2.3.3 Diâmetro

Conforme discutido por com Fabricio, Brito e Vittorino (2017 *apud* Marques, Luiz e Silva 2020), a base dos colmos, as quais possuem maior diâmetro, é a que suporta

as maiores solicitações de tração, devido à ação dos ventos.

Ghavami, Barbosa e Moreira (2017), acrescentam que a diferença entre o maior e o menor diâmetro, dividida pelo comprimento do colmo (conicidade), é limitada a 0,67% para o emprego do bambu em estruturas. Algumas espécies podem atingir 25cm de diâmetro em condições normais.

2.3.4 Espessura da parede

Do mesmo modo que ocorre com o diâmetro, a espessura da parede diminui da base para o topo. No entanto, Vale, Moreira e Martins (2017 *apud* Almeida 2023), ressalta que esse fator contribui para o aumento de sua resistência que ocorre da parte interna para a externa, com a diminuição do parênquima e aumento das fibras.

No que diz respeito à espessura da parede para fins estruturais, Caeiro (2010) declara que não é admissível espessura inferior a 1cm.

2.3.5 Absorção de água

Quando o bambu é exposto a variações de umidade abaixo do ponto de saturação das fibras, que é aproximadamente 20%, ele sofre consideráveis alterações dimensionais. Sua retração ocorre desde o início do processo de secagem, sendo a higroscopicidade dos extrativos presentes nas células de parênquima, o principal fator na absorção de água pelo colmo já seco (Drumond e Wiedman, 2017).

É destacado por Ghavami, Barbosa e Moreira (2017), que se a resistência do bambu se apresenta muito baixa, com umidade de equilíbrio na faixa dos 10%, é sinal de que o tempo mínimo de maturação não foi respeitado.

Ghavami, Barbosa e Moreira (2017), alertam que em hipótese alguma, devem ser utilizadas estruturas de bambu com temperatura de trabalho que ultrapasse os 65° C.

2.3.6 Peso específico

Segundo Murad (2007), ao comparar a resistência à tração do bambu com seu peso específico, obtém-se um valor 2,77 vezes maior do que o do aço. Consoante Cruz(2022) reitera que essa razão é superior à do aço CA50, o que possibilita construções mais leves.

Isaia (2017) cita os valores ideais de peso específico para bambus mais apropriados para a construção de 0,8kg/dm³ a 0,95kg/dm³. Na Tabela 1 é apresentado as características físicas de algumas espécies de bambu.

Tabela 1: Características físicas de algumas espécies.

Espécie	L (m)	D (cm)	t (cm)	d (cm)
Dendrocalamus asper	20- 30	8-20	1,1-2	20-45
Dendrocalamus giganteus	24-60	10-20	2,5	40-50
Guadua augustifólia	Até 30	14-20	0,12-0,15	36-45
Gagantochloa levis	Até 30	5-16	1-1,2	45
Plyllastachys Pubescens	out/20	15-18	0,8-1,4	20-50

Fonte: Almeida (2023), (adaptado pelo autor). (L) comprimento do colmo; (D) diâmetro externo; (t) espessura da parede; (d) distância entre nós.

2.4 Propriedades Mecânicas do Bambu

Fabricio, Brito e Vittorino (2017), declara que a resistência longitudinal, também conhecida como resistência paralela às fibras, é a predominante. Devido à orientação das fibras ao longo do eixo do colmo, o bambu possui maior resistência à tração do que à compressão. O módulo de elasticidade na direção paralela às fibras varia de acordo com a posição do colmo. Ainda segundo Fabricio, Brito e Vittorino (2017), a resistência à compressão paralela às fibras é, em geral, cerca de 30% menor, se comparada à resistência à tração no mesmo sentido.

Goh *et al.,*(2020 *apud* Marques, Luiz e Silva 2020), explicam que isso se deve ao fato de a distribuição das fibras ocorrer de forma heterogênea no sentido do eixo radial, pois a resistência diminui da parte externa para o centro do colmo, resultado da presença mais densa da matriz de parênquima.

A Fig. 4 apresenta a influência do teor de umidade na resistência à compressão dos colmos.
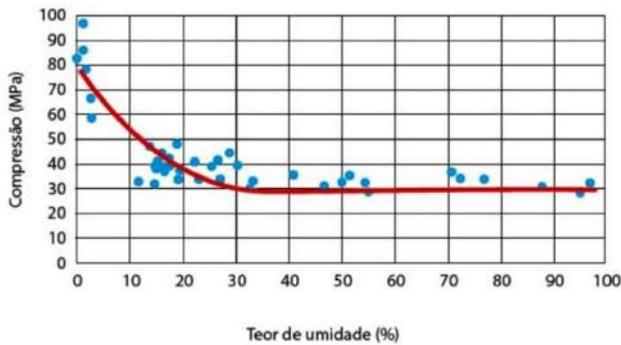
Fig.4: Resistência à compressão.

Fonte: Fabricio, Brito e Vittorino (2017).

Conforme indicado por Santos (2021), a força de cisalhamento atua na mesma direção das fibras. Pesquisas evidenciam que esse é um dos aspectos desfavoráveis do bambu, o que pode resultar em possíveis ocorrências de fissuras. De maneira geral, é observado que a resistência ao cisalhamento do bambu tende a diminuir à medida que o teor de umidade aumenta, conforme mencionado por Pereira (2012). Na Tabela 2 é mostrado as propriedades mecânicas de algumas espécies de bambu.

Tabela 2: Propriedades mecânicas de algumas espécies.

Espécie	σ_t (MPa)	σ_c (MPa)	σ_f (MPa)	τ (MPa)
Dendrocalamus giganteus	135	40	108	46
Dendrocalamus asper	285	28	89	6,6
Gagantochloa levis	296	30	84	7,2
Guadua augustifólia	237	29	82	8
Plyllastachys Pubescens	120	42	-	-

Fonte: Santos e Madalosso (2020 *apud* Almeida 2023), (adaptado pelo autor). (σ_t) tração; (σ_c) compressão; (σ_f) flexão; (τ) cisalhamento.

2.5 Normatização e o uso do bambu na construção civil

Souza, Leão e Quaresma (2020), citam que o avanço no setor da construção civil tem levado ao estudo contínuo de materiais alternativos para substituir os convencionais, como por exemplo, o concreto e o aço.

No Brasil, os primeiros estudos científicos relativos ao bambu tiveram início em 1979, no Departamento de Engenharia Civil da Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), desde então, foram desenvolvidos vários programas de investigação do uso do bambu e das fibras naturais (sisal, coco, piaçava e polpa celulótica de bambu) como materiais de baixo impacto ambiental, para serem empregados na construção

(Isaia,2017). Através de um projeto iniciado em 2017 foi elaborada a primeira norma brasileira, dirigida às estruturas de bambu, com base na ISO 22156-Bamboo Structural Design (Cruz, 2022).

Em 2020, a Associação Brasileira de Normas Técnicas (ABNT) por meio do Comitê Brasileiro da Construção Civil (CB-002), divulgou essa norma dividida em duas partes. A primeira trata do planejamento e dimensionamento de estruturas feitas de bambu (NBR 16828-1), enquanto a segunda diz respeito aos procedimentos de teste para determinar as propriedades físico-mecânicas do bambu (NBR16828-2).

Adicionalmente, em março de 2023, foi publicada a NBR17043, que trata da colheita, tratamento imunizante e classificação das varas de bambu para uso estrutural. Esta, elaborada pelo comitê ABNT/CB-002 Construção Civil, CEE: 002:126.012 Estruturas de Bambu.

Conforme explanado por Oliveira (2013), a utilização do bambu na construção civil remonta a séculos, sendo sua resistência comprovada em diversos ensaios distintos.

Por apresentar propriedades mecânicas favoráveis, grande disponibilidade e natureza sustentável, o bambu tem se mostrado um material de construção promissor (Agnol, 2019).

De acordo com Beraldo & Rivero (2003), o bambu possui boas características físicas, o que o credencia para aplicação estrutural na construção civil. Além disso, o bambu é altamente resistente à tração, similar ao aço, e sua resistência à compressão é semelhante à do concreto. Os autores também elucidam que o uso do bambu é uma boa opção para construções em áreas de difícil acesso, devido a sua baixa massa específica.

No entanto, Padovan (2010), destaca que um dos principais obstáculos ao usar o bambu em larga escala na construção civil é a forma como as conexões são abordadas para transmitir as cargas estruturais, em um processo análogo ao que é feito com materiais convencionais como o aço e a madeira.

Em conformidade, Alves (2019), acrescenta como outro fator de significativa importância, o fato de o bambu ser um material anisotrópico, ou seja, possui propriedades distintas ao longo do seu colmo. No entanto, de forma positiva, os diafragmas existentes transversalmente em seu sentido longitudinal, tendem a evitar a flambagem lateral do tubo.

Muitos projetos ao redor do mundo incorporam o uso do bambu, sendo que em alguns casos, ele assume o papel central na estrutura da construção. As Figuras 5 à 8 ilustram alguns exemplos dessas realizações.

Fig.5: Pontilhão sobre braço de rio
Fonte:Oliveira (2013).

Fig.6: Casa contemporânea
Fonte: Andrade (2022)

Fig.7: Casa estruturada com bambu
Fonte:Oliveira (2013).

Fig.8: Grandes vãos
Fonte:Andrade (2022).

Como evidenciado anteriormente, devido à sua versatilidade, o bambu pode ser empregado em estruturas e vencer grandes vãos.

III. CONCLUSÃO

O bambu como material de construção é uma alternativa útil. Em relação às suas propriedades, o bambu apresenta grande resistência e boa trabalhabilidade, além de possuir características semelhantes às do aço, principalmente quanto à resistência à tração.

Não obstante sua ampla utilização no ramo da construção civil, no Brasil, persiste uma escassez de estudos abrangentes sobre suas características físicas e mecânicas minimizada pela recente elaboração de normas técnicas destinada às estruturas de bambu.

Nesse sentido, os desafios em termos de tecnologia e desenvolvimento de técnicas de utilização do bambu na construção civil, o que coloca o Brasil em desvantagem em relação a outras nações, podem ser superados.

REFERÊNCIAS

[1] AGNOL, Flávia Cristina Dall'. Estudo da viabilidade do uso do bambu em vigas de concreto armado em substituição ao aço. Trabalho de Conclusão. Universidade de Caxias do Sul. Caxias do Sul, 2019.

[2] AGOPYAN, Vahan; JOHN, Vanderley Moacyr. O desafio da sustentabilidade na construção civil. São Paulo: Blucher, 2011.

[3] ALMEIDA, J. de. Potential uses for BAMBOO. Sustainability in Debate, [S. l.], v. 7, n. 3, p. 178–195, 2016.

[4] ALMEIDA, Victor. Revisão de literatura: aplicabilidade do bambu na construção civil. 2023. Disponível em: https://repositorio.ifgoiano.edu.br/handle/prefix/3820. Acesso em 12/nov. 2023.

[5] ALVES, Amanda Altrão. Uso do bambu na construção civil: aplicações estruturais e arquitetônicas para um desenvolvimento sustentável. 2019. Trabalho de Conclusão

de Curso (Bacharelado em Engenharia Civil) - Universidade Tecnológica Federal do Paraná, Campo Mourão, 2019. Disponível em: http://repositorio.utfpr.edu.br/jspui/handle/1/25425. Acesso em: 17 out. 2023.

[6] ANDRADE, P.B. Estudo do uso: bambu como elementos construtivo em praças urbanas. Cabedelo, PB, 2022.

[7] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 17043: Varas de bambu para uso estrutural – Colheita, tratamento preservativo e classificação pelo diâmetro. Rio de Janeiro, 2023.

[8] CAEIRO, João Gabriel de Matos. Construção em bambu. 2010. Tese de Doutorado. Faculdade de Arquitectura de lisboa. Disponível em: http://hdl.handle.net/10400.5/3337. Acesso em 3 out. 2023.

[9] COLLIS, J. & HUSSEY, R. Business Research: a Practical Guide for Undergraduate and Postgraduate Students, 2. ed. Porto Alegre: Bookman, 2005.

[10] CRUZ, Luisa Souza Frade da; BARROS, Marcelo Miranda. Bambu Estrutural: Possibilidades para uma Engenharia Sustentável. MIX Sustentável, v. 8, n. 2, p. 79-92, mai. 2022. ISSN-e: 24473073.Disponível em: . DOI: http://dx.doi.org/10.29183/2447- 3073.MIX2022.v8.n1.79-92. Acesso em: 2 nov. 2023.

[11] DRUMOND, Patrícia Maria et al. Bambus no Brasil: da biologia à tecnologia. Rio de Janeiro: Instituto Ciência Hoje, 2017. Disponível em: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1078373. Acesso em: 25 nov. 2023.

[12] FABRICIO, Márcio Minto; BRITO, Adriana C.; VITTORINO, Fúlvio. Avaliação de desempenho de tecnologias construtivas inovadoras: conforto ambiental, durabilidade e pós-ocupação. Porto Alegre: Antac, 2017.

[13] FERREIRA, Gisleiva Cristina dos Santos. Vigas de concreto armadas com taliscas de bambu Dendrocalamus Giganteus. 2007. 174p. Tese (doutorado) - Universidade Estadual de Campinas, Faculdade de Engenharia Civil, Arquitetura e Urbanismo, Campinas, SP. Disponível em: https://hdl.handle.net/20.500.12733/1605374. Acesso em: 3 out. 2023.

[14] GHAVAMI, Khosrow. Retração, Fluência e Fratura em Compósitos Cimentícios Reforçados com Polpa de Bambu. 2006. Tese de Doutorado. PUC-Rio.

[15] GHAVAMI, Khosrow; BARBOSA, Normando Perazzo; MOREIRA, Luis Eustáquio. Bambu como material de engenharia. Avaliação de Desempenho de Tecnologias Construtivas Inovadoras: Conforto Ambiental, Durabilidade e Pós-Ocupação, p. 305-348, 2017. DOI: http://dx.doi.org/10.26626/978-85-5953-029-2.2017C0012.p.305-348. Acesso em: 18 nov. 2023.

[16] GIL, Antônio Carlos. Como elaborar projetos de pesquisa. 6. ed. São Paulo: Atlas, 2018.

[17] ISAIA, G. Cechella, Materiais de construção civil e princípios de ciência e engenharia de materiais, 3a. São Paulo: Arte Interativa, 2017.

[18] LIMA, Mateus Fernandes Vilela. O direito à moradia e as políticas públicas habitacionais brasileiras da segunda década do século XXI. Geo UERJ, n. 36, p. 48406, 2020. DOI: https://doi.org/10.12957/geouerj.2020.48406. Acesso em 18 out. 2023.

[19] MARÇAL, Vitor Hugo Silva; AMBIENTAL, CIVIL E. Uso do bambu na construção civil. Projeto final em Engenharia Civil e Ambiental. Faculdade de Tecnologia, Universidade de Brasília. Brasília, 2008.

[20] MARQUES, Sara Corrêa; LUIZ, Gabriel Andrade; SILVA, Thalles Gumieri da. Emprego do bambu na construção civil. Epitaya E-books, *[S. l.]*, v. 1, n. 12, p. 72-81, 2020. DOI: 10.47879/ed.ep.2020144p72. Disponível em: https://portal.epitaya.com.br/index.php/ebooks/article/view/51. Acesso em: 18 nov. 2023.

[21] MURAD, Mauricio. A violência e o futebol: dos estudos clássicos aos dias de hoje. FGV Editora, 2007.

[22] NOIA, Paula Regina da Cruz. Sustentabilidade socioambiental: Desenvolvimento de sistemas construtivos em bambu no Vale do Ribeira, SP. 2012. Tese de Doutorado. Universidade de São Paulo. DOI: https://doi.org/10.11606/D.16.2012.tde-04032013-095707. Disponível em: https://www.teses.usp.br/teses/disponiveis/16/16132/tde-04032013-095707/en.php. Acesso em: 2 nov. 2023.

[23] NUNES, Gabrielly da Mota; JÚNIOR, Antônio da Silva Sobrinho & DOS SANTOS PASTOR, Jaiane. O uso do bambu como material estrutural na construção civil. Revista Principia-Divulgação Científica e Tecnológica do IFPB, n. 55, p. 152-164, 2021. Acesso em: 20 set. 2023.

[24] OLIVEIRA, Luiz Fernando Andrade de. Conhecendo bambus e suas potencialidades para uso na construção civil. 2013. Disponível em: http://hdl.handle.net/1843/BUBD-9GBPWL. Acesso em: 22 out. 2023.

[25] PADOVAN, Roberval Bráz. O bambu na arquitetura: desing de conexões estruturais. Dissertação (Mestrado em Design) – Universidade Estadual Paulista "Júlio de Mesquita Filho", campus de Bauru, Bauru, 2010.

[26] PEREIRA, Beatriz Oliveira. Estudo de concretos com adição de bambu. 2018. Trabalho de Conclusão de Curso. Universidade Tecnológica Federal do Paraná. Disponível em: http://repositorio.utfpr.edu.br/jspui/handle/1/6445. Acesso em: 10 out. 2023.

[27] PEREIRA, Marco Antonio dos Reis. Projeto bambu: introdução de espécies, manejo, caracterização e aplicações. 2012. 200 f. Tese (livre-docência) - Universidade Estadual Paulista, Faculdade de Engenharia, 2012. Disponível em: http://hdl.handle.net/11449/106710. Acesso em: 5 nov. 2023.

[28] RIBAS, Rodrigo Pinheiro. Bambu: planta de grande potencial no desenvolvimento sustentável. 2015.

[29] RIVERO, Lourdes Abbade; BERALDO, Antonio Ludovico. BAMBU LAMINADO COLADO (BLC). Revista Floram: Floresta e Ambiente, Rio de Janeiro, v. 10, n. 2, p.36-46, dez. 2003. Disponível em:

http://www.floram.org/files/v10n2/v10n2a5. Acesso em: 30 ago. 2023.

[30] RUSCH, F.; HILLIG, Éverton; CEOLIN, G. B. Anatomia de hastes adultas de bambu: uma revisão. Pesquisa Florestal Brasileira, *[S. l.]*, v. 38, 2018. DOI: 10.4336/2018.pfb.38e201701530. Disponível em: https://pfb.cnpf.embrapa.br/pfb/index.php/pfb/article/view/1530. Acesso em: 18 nov. 2023.

[31] SANTOS, Erick Breno Azevedo dos. Análise energética de uma caldeira mista utilizando cavaco de bambu como combustível. 2021. 58 p. Trabalho de Conclusão de Curso (Graduação em Engenharia Mecânica) - Universidade Federal do Rio Grande do Norte, Natal, 2021. Disponível em: http://monografias.ufrn.br/handle/123456789/11468. Acesso em: 10 nov. 2023.

[32] SILVA, Gilson Alves; SILVA, João Victor Maia. Sistema construtivo em bambu - CALFITICE. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020. Anais [...]. Porto Alegre: ANTAC, 2020. p. 1–8. DOI: 10.46421/entac.v18i.1025. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1025. Acesso em: 18 nov. 2023.

[33] SOUZA, Fellipe Morais; LEÃO, Lucas Osório; QUARESMA, Wanessa Mesquita Godoi. Estado da Arte do Bambu na Construção Civil. Brazilian Journal of Development, v. 6, n. 4, p. 19637-19653, 2020. DOI:10.34117/bjdv6n4-216. Acesso em 15 out. 2023.

[34] TIBURTINO, Rogy Frigeri; PAES, Juarez Benigno; BERALDO, Antônio Ludovico; Arantes, Marina Donaria Chaves; Brocco, Victor Fassina**.** Tratamento preservativo de duas espécies de bambu por imersão prolongada e *Boucherie* modificado. Floresta e Ambiente, v. 22, p. 124-133, 2015. DOI: https://doi.org/10.1590/2179-8087.032113. Disponível em: https://www.scielo.br/j/floram/a/Pd8PFkcNFGCBnfcwMYSspqx/?lang=pt&format=html. Acesso em: 20 set. 2023.

Convolutional Sparse Coding Multiple Instance Learning for Whole Slide Image Classification

Md Rony Molla, Ma Jian Fen

College of Computer Science and Technology (College of Data Science), Taiyuan University of Technology, China

Abstract*— Multiple Instance Learning (MIL) is commonly utilized in weakly supervised whole slide image (WSI) classification. MIL techniques typically involve a feature embedding step using a pretrained feature extractor, then an aggregator that aggregates the embedded instances into predictions. Current efforts aim to enhance these sections by refining feature embeddings through self-supervised pretraining and modeling correlations between instances. In this paper, we propose a convolutional sparsely coded MIL (CSCMIL) that utilizes convolutional sparse dictionary learning to simultaneously address these two aspects. Sparse dictionary learning consists of filters or kernels that are applied with convolutional operations and utilizes an overly comprehensive dictionary to represent instances as sparse linear combinations of atoms, thereby capturing their similarities. Straightforwardly built into existing MIL frameworks, the suggested CSC module has an affordable computation cost. Experiments on various datasets showed that the suggested CSC module improved performance by 3.85% in AUC and 4.50% in accuracy, equivalent to the SimCLR pretraining (4.21% and 4.98%) significantly of current MIL approaches.*

I. INTRODUCTION

The utilization of gigapixel resolution in digital whole slide imaging (WSIs) facilitates the comprehensive examination and analysis of the complete tissue sample within a singular image. Nevertheless, pathologists encounter substantial difficulties due to the magnitude and intricacy of the images [1]. Consequently, there is a growing need for automated workflows to facilitate WSI analysis. Because of this, deep learning-based methods have been increasingly used and developed in this sector [2,3,4,5,6,7,8,9]. The massive size of WSIs and the lack of annotations at the pixel level make deep learning approaches difficult to deploy [2]. To tackle these issues, approaches based on weakly-supervised multiple instance learning (MIL) have been suggested [6,7,8,9].

In the framework of MIL for WSI classification, each WSI is seen as a collection of non-overlapping patches that are extracted from the WSI slide. Each patch is considered as an unlabeled instance. The bag is classified as positive if at least one of the occurrences demonstrates the presence of disease, and negative otherwise. A commonly employed methodology for conducting MIL in WSIs involves a two-step process. Initially, the cropped patches undergo a process of conversion into feature embeddings by means of a fixed feature extractor. A fixed extractor is more desirable than a learned one since the computational cost of back-propagating with a large number of instances in a bag is prohibitively expensive. Next, a MIL aggregator is utilized to merge the embeddings of local instance features in order to get bag-level predictions. The potential sub-optimality of a two-stage learning scheme arises from the presence of noisy feature embeddings and imbalanced instances.

Specifically, the limited representation of positive instances within a positive bag can lead to the MIL aggregator learning an inaccurate mapping between embeddings and labels. Additionally, the limited supervisory signal poses a hindrance to the MIL aggregator's ability to capture correlations among instances [7, 8, 10].

Prior endeavors at MIL addressed these two obstacles individually. The initial category of approaches centered on enhancing the feature embeddings that were extracted through the use of self-supervised pretraining [7,10,11,12].

On the other hand, these techniques necessitate a large amount of data and an additional computationally intensive training phase. In order to eliminate negative instances, the second group of approaches concentrated on enhancing the MIL aggregator to better capture cross-instance correlations and imposing sparsity limitations on the local instance attention (e.g., picking k most significant instances) [13,14]. Better sparse instance feature embeddings that can model the invariance of the same type of biological tissues would also ease the duty of the MIL aggregator, therefore there is a strong relationship between these two types of approaches. Sparse feature embeddings, which are a low-dimensional version of the feature extractor's initial instance embeddings, are also advantageous to WSI representation since the high-dimensional WSI representation is located on a low-dimensional manifold, according to empirical evidence [10, 12].

Convolutional Sparse Coding (CSC) applies sparse representations to image or signal data and exploits local dependencies through convolutional processes. In signal processing and machine learning, sparse coding finds a sparse basis function representation of incoming data. We built an end-to-end learning-optimizable CSC module for convolutional sparse coding learning. Our new MIL framework, convolutional sparsely coded MIL (CSC-MIL), uses convolutional dictionary learning to improve initial feature embeddings. Traditional sparse dictionary learning algorithms are incompatible with deep neural networks and need considerable hyperparameter adjustment. Since it is complementary to current MIL frameworks, the proposed CSC module can be incorporated with them with reasonable extra processing. The experimental findings on different datasets and tasks proved that the suggested strategy helped state-of-the-art MIL methods perform better.

II.   RELATED WORK

Methods for MIL can be broadly classified into two primary categories: instance-level MIL and bag-level MIL. In general, the instance-level approaches [15,16,17,18,19] include training a neural network to predict instance-level labels. These labels are assigned by propagating the bag-level label to each instance. The researchers combine the anticipated labels at the instance level in order to get the appropriate label at the bag level. However, as a consequence of the limited number of positive examples in a bag that are linked to a disease in whole slide images (WSIs), the negative cases within a positive bag are frequently incorrectly labeled. Despite multiple endeavors to refine the instance-level labels, empirical investigations have repeatedly demonstrated that instance-level approaches provide lower performance in comparison to their bag-level counterparts [8,20].

The bag-level multiple instance learning (MIL) approaches [6,7,8,9,20,13,21,22,23,14,12] employ a two-stage learning process. In this process, the methods initially transform the instances into a feature representation by utilizing a pretrained feature extractor. Subsequently, they employ MIL aggregation techniques to generate predictions at the bag-level. Previous investigations on bag-level MIL have predominantly concentrated on two main avenues. One potential option for improvement involves enhancing the MIL aggregator. The attention-based MIL [7,6] transformed non-parametric poolings like max/mean-pooling [20] into trainable ones using an attention mechanism. However, initial approaches examined each incident separately without considering similarities. Further research has addressed this restriction by using graph convolutional networks [14], non-local attention [7], transformers [8], and knowledge distillation [9]. The second approach involves enhancing feature embedding through self-supervised pretraining [7,10,11,12]. However, these approaches require ample data for task-specific training and are computationally costly.

The concept of employing sparse coding in network designs can be attributed to the research conducted by [24] who explored the application of unrolling sparse coding algorithms, such as ISTA, to acquire knowledge about the sparsifying dictionary. Several recent studies have investigated the utilization of deep networks using convolutional sparse coding layers for various tasks such as image denoising, picture restoration, and image classification with network normalization [25,26,27,28]. The efficacy of neural networks has primarily been established on datasets of limited or moderate sizes, particularly in the context of tasks such as picture categorization or production. In a recent study by [29], it was shown that convolutional sparse coding-inspired networks have achieved notable performance in image classification tasks using extensive picture datasets like ImageNet-1K.

Our work is similar to [10], which improved feature embedding using low-rank guided self-supervised pre-training and an attention-based MIL aggregator that utilizes

low-rank properties. However, it requires further self-supervised training and is customized for a certain MIL aggregator. Our approach may increase features and represent global instance similarities using a single module, making it easy to integrate into current MIL methods.

III.   METHODOLOGY

To maintain the integrity of our analysis, we will focus on the specific case of bag-level binary MIL classification. The investigation aims to discover a correspondence between a collection of bags $x_1, x_2, \cdots, x_b$, and their respective labels $z_1, z_2, \cdots, z_b$, with $x_{i,j}$ is a positive integer greater than or equal to n instances $(x_{i,1}, x_{i,2}, \cdots, x_{i,n})$ and $\mathbb{R}^p$ is the dimension of each instance $(x_{i,1})$. The mathematical definition of the bag-level binary MIL classification is as follows:

$$y_i = \begin{cases} 0 & iff \sum_{j=1}^{n} y_{i,j} = 0 \\ 1 & otherwise \end{cases} \quad (1)$$

where $y_{i,j} \in <\{0,1\}$ represents the instance-level label of the i-th bag that is unknown, and n may differ between bags. A bag-level prediction is generated when a MIL aggregator aggregates the instance-level predictions contained within a bag.

$$\hat{y}_i = f_{cls}(\sigma(\phi_\omega(x_{i,1}), \phi_\omega(x_{i,2}), \cdots, \phi_\omega(x_{i,n})) \quad (2)$$

The function $f_{cls}(\cdot)$ represents a classifier at the bag level. The symbol ϕ_ω represents an embedding network that is parameterized by ω and operates at the instance level. The function σ is a permutation-invariant function. In this study, we examine four commonly used MIL pooling techniques, namely attention-based [6], non-local-based [7], transformer-based [8], and knowledge distillation-based [9].

3.1 SPARSELY CODED IN MIL

Empirical evidence supports the notion that the low-dimensional representation of instance embeddings significantly enhances the WSI representation [10, 12]. We assume the initial instance embeddings $\phi_\omega(x_i)$ can be represented in a low-dimensional space by a linear combination of s $<<$ m atoms from an over-complete dictionary $D \in \mathbb{R}^{p \times m}$, where m is the number of atoms in the dictionary. A classic Sparse Coding (SC) method for signals is to divide them into patches and solve for each

$$\min||z||_0 s.t. x = Dz \quad (3)$$

3.2 CONVOLUTIONAL SPARSE CODING

The CSC model is derived from the classical SC model by exchanging the matrix with the convolutional operator.

$$x = \sum_{i=0}^{m-1} d_i * z_i \quad (4)$$

Where $x \in \mathbb{R}^{n_1 \times n_2}$ is the input signal, $d_i \in \mathbb{R}^{k \times k}$ a local convolution filter, and $z_i \in \mathbb{R}^{n_1 \times n_2}$ a sparse feature map of the convolutional atom d_i the l_1 minimization problem for CSC formulated as

$$\arg \min_{d,z} \frac{1}{2}||x - \sum_{i=0}^{m-1} d_i * z_i||_2^2 + \lambda \sum_{i=0}^{m-1} ||z_i||_1 \quad (5)$$

The CSC includes the entire input signal, unlike typical SC, which splits x into patches or segments. A learned atom of a certain edge orientation can globally represent all edges of that orientation in the image since the CSC model is spatially invariant.

Since convolutions are linear and the CSC model is a classical SC model, where D_{conv} is a concatenation of Toepltiz matrices, it can be interpreted to be a variant of classical SC. To format the aim in eq 5 replace the universal dictionary D with D_{conv}. Representing the CSC model as matrix multiplication is inefficient in memory and computation. Each element of x requires $n_1 \times n_2 \times m$ multiply and accumulate operations compared to convolution formation, which only requires s MACs (assuming s $<<$ n_1, n_2). ISTA iterations for CSC reads as:

$$z_{k+1} = S_{\lambda/L}\left(z_k + \frac{1}{L}d * (x - d * z_k)\right) \quad (6)$$

where $d \in R^{s \times s \times m}$ is an array of m s $\times$ s filters, $d * z = [flip(d_0) * x, \cdots, flip(d_{m-1}) * x]$ and $d * z = \sum_{i=0}^{m-1} d_i * z_i$. The flip($d_i$) operation flips the order of entries in d_i in both dimensions.

$$z_{k+1} = S_\theta\left(z_k + w_e * (x - w_d * z_k)\right) \quad (7)$$

the variables w_e, w_d, and θ are fully trainable and independent. We proposed the variable c to allow for numerous channels in the initial signal, such as color channels.

3.3 LEARNING THE OPTIMAL λ

The selection of the sparsity regularization strength λ is a crucial parameter in the ISTA with Acceleration. Tuning the value of λ is crucial for balancing sparsity and expressiveness in Convolutional Sparse Coding (CSC). However, within the framework of NA-MIL, the selection of the ideal λ value may differ between bags, posing a significant challenge for manual tuning. To achieve this objective, we framed the assessment of the optimal λ_i for each bag as a regression task. The parameter λ_i was represented as a feed-forward network (FFN) f_θ (ϕ_ω (x_i)). Here, θ represents the parameters of the network. The FFN in this study was composed of three fully-connected layers, and ReLU activation was performed on each layer. A mean pooling layer was incorporated following the fully connected feedforward neural network (FFN) to generate a

single numerical output for λ_i. The average pooling method was selected because the sparsity is similarly distributed across all target instance embeddings in a bag.

3.4 LEARNING THE OPTIMAL STEP SIZE

The choice of the step size has a crucial role in determining the convergence behavior of the ISTA with Acceleration (ISTA-ACC) algorithm. One common approach for learning the step size is line search, where the step size is determined dynamically at each iteration based on the properties of the objective function. Instead of utilizing a predetermined step size (α), it is suggested to

Table. 1: Performance comparison on two classical MIL benchmark datasets

Method	Musk1	Musk2
mi-Net	0.886 ± 0.003	0.857 ± 0.002
MI-Net	0.887 ± 0.015	0.859 ± 0.012
Mi-Net with DS	0.894 ± 0.003	0.084 ± 0.002
Mi-Net with RC	0.967 ± 0.003	0.960 ± 0.002
ABMIL	0.892 ± 0.015	0.858 ± 0.012
ABMIL-Gated	0.900 ± 0.015	0.863 ± 0.012
GNN-MIL	0.917 ± 0.003	0.892 ± 0.002
DP-MINN	0.907 ± 0.003	0.926 ± 0.002
NLMIL	0.921 ± 0.003	0.910 ± 0.002
ANLMIL	0.912 ± 0.015	0.884 ± 0.012
DSMIL	0.932 ± 0.003	0.930 ± 0.002
ABMIL w/CSC	0.957 ± 0.015	0.957 ± 0.008
ABMIL-Gated w/CSC	0.969 ± 0.003	0.961 ± 0.002

employ a line search technique to choose the most favorable step size throughout each iteration. At every iteration k, conduct a line search in the direction of the negative gradient in order to get the optimal step size that minimizes the objective function. Two commonly used line search approaches in optimization algorithms are backtracking line search and quadratic interpolation.

IV. EXPERIMENTS

4.1 DATASETS

A series of tests were done on many datasets, encompassing two well-established MIL benchmarks, namely the MNIST-bags dataset [6], the CAMELYON16 dataset [30], and the Cancer Genome Atlas non-small cell lung cancer (TCGA-NSCLC) dataset. These experiments were carried out to assess and verify the efficacy of the proposed method.

Classical MIL benchmark datasets are MUSK1 and MUSK2. The MUSK1 and MUSK2 datasets estimate pharmacological effects based on molecular configurations. Each bag has several molecular conformations. The bag label is positive if at least one conformation has the intended pharmacological effect, and negative if none is effective [31].

The MNIST-bags dataset [6] contains random bags of grayscale handwritten digits from the MNIST dataset. As per [6], the digit of interest was '9', and any bag with at least one instance of it was considered affirmative. Ten incidences per bag were averaged, with a standard deviation of two. After adding the proposed SC module into attention-based MIL, we used this dataset for explanations.

The public WSI dataset CAMELYON16 detects metastatic breast cancer in lymph node tissue. The dataset contains 399 lymph node tissue WSIs (one corrupted sample was deleted), split into 270 training samples and 129 testing samples. Pathologists annotate each WSI with a binary label indicating metastatic cancer presence or absence in the lymph node tissue. Cancerous tissue areasof each WSI are also annotated in the dataset. After following the preprocessing steps in [7], we trimmed the WSIs into 224×224 non-overlapping patches. Approximately 3.37 million patches at $\times 20$ magnification were produced, averaging 8451 per bag. The TCAGA-NSCLC dataset is utilized for the purpose of distinguishing between two sub-types of lung cancer, namely lung squamous cell carcinoma and lung adenocarcinoma. Following [7], we separated 1037 diagnostic WSIs into 744 training, 83 validation, and 210 testing sets. Following the same

Table.2: Evaluation of state-of-the-art approaches on CAMELYON16 and TCGA-NSCLC datasets. AUC and classification accuracy (%) were reported.

	Method		Camelyon16		TCGA-NSCLC	
			Accuracy	AUC	Accuracy	AUC
ResNet-18 ImageNet Pretrained	ABMIL-Gated		80.55	80.40	81.72	91.22
		+CSC	82.16	83.41	84.50	94.28
		Δ	+1.55	+4.13	+2.78	+2.06
	DSMIL		82.82	85.76	77.67	89.15
		+CSC	84.37	86.73	86.23	92.26
		Δ	+1.55	+0.97	+8.56	+3.11
	TransMIL		80.82	81.76	84.67	92.15
		+CSC	82.37	86.73	90.23	94.26
		Δ	+1.55	+4.97	+5.56	+2.11
	DTFD(maxS)		82.95	89.54	84.29	90.37
		+CSC	86.05	92.55	87.57	94.20
		Δ	+3.10	+3.01	+3.34	+3.83
ResNet-18 SimCLR Pretrained	ABMIL-Gated		82.05	82.05	85.72	90.22
		+CSC	85.16	86.41	88.50	93.28
		Δ	+3.11	+0.34	+2.78	+3.06
	DSMIL		86.82	85.76	86.67	93.15
		+CSC	88.37	87.73	90.23	95.26
		Δ	+3.11	+1.97	+3.56	+1.76
	TransMIL		86.82	85.76	86.67	93.15
		+CSC	88.37	87.73	90.23	95.26
		Δ	+3.11	+1.97	+3.56	+1.76
	DTFD(maxS)		82.95	89.54	84.29	90.37
		+CSC	86.05	92.55	87.57	94.20
		Δ	+3.10	+3.01	+3.34	+3.83

preprocessing as the CAMELYON16 dataset, about 10.30 million patches were retrieved at ×20 magnification. Each bag averaged 10355 patches.

4.2 BASELINES

We compared the proposed method against deep learning-based MIL methods, such as mi-Net and MI-Net [20], ABMIL and ABMIL-Gated [6], GNN-MIL [32], DP-MINN [33], and three non-local MIL pooling methods (NLMIL [34], ANLMIL [22], and DSMIL) on classical MIL benchmark datasets. For WSI classification, we investigated integrating the CSC module into four MIL

aggregators: ABMIL with gated attention [6], DSMIL [7], TransMIL [8], and DTFD-MIL with MaxS[9].

4.3 EXPERIMENTAL SETTINGS

In this study, different experimental approaches were used for different datasets. We ran 10-fold cross-validation on conventional MIL datasets with five repetitions each experiment, focusing on classification accuracy. We tested the effectiveness of the suggested strategy by integrating the CSC module into the ABMIL framework utilizing two attention mechanisms: ABMIL w/ SC and ABMIL-Gated

Table.3: Proposed CSC module parameter selections the number of atoms in dictionary when L = 6

# Atoms(m)	# Params	FLOPS	AUC
m=4	59.53K	10.25K	86.61
m=8	94.03K	18.43K	88.31
m=16	189.13K	86.13K	90.45
m=32	561.65K	888.60K	90.75

w/ CSC. Additionally, 200 bags were used for training and 50 for testing in the MNIST-bags dataset. We used the training and testing partitions for the two WSI datasets. We tested features from two pretrained ResNet-18 models. Evaluation metrics included classification accuracy and AUC values.

This work trained all models using cross-entropy loss. All results in tables 1 and 2 had m = 16 atoms in a dictionary and L = 6 layers. The batch size was 1 for all tests. Models were trained on conventional MIL datasetsusing an Adam optimizer for 40 epochs, with initial learning of 1×10^{-4} and l2 weight decay of 5×10^{-4}. The initial learning rate was changed using a cosine annealing scheduler. We used the identical training settings on the MNIST-bags dataset but with a 5×10^{-4} initial learning rate and 1×10^{-4} weight decay. For the WSI classification tasks, we trained all four MIL aggregators for 200 epochs using default settings.

4.4 RESULTS

After integrating the proposed CSC module, ABMIL w/CSC and ABMIL-Gated w/CSC exceeded state-of-the-art classification accuracy approaches on all five MIL benchmark datasets (1). The ABMIL-Gated w/CSC outperformed the previous state-of-the-art accuracy by 2.5%, with 3.7% on MUSK1, 3.7% on MUSK2, and 3.1% on MUSK2. Furthermore, the accuracy of the ABMIL-Gated w/SC demonstrated the greatest stability, as evidenced by its average standard deviation of 0.0054.

Fig.1: Comparison of attention weight on positive bags on MNIST-bags ABMIL w/o CSC module and ABMIL w/ CSC module

The integration of the suggested CSC module consistently enhanced the performance of the four various types of MIL aggregators when combined with two distinct pre-training approaches, as shown in 2. This proves that the

suggested CSC module's performance improvement is independent of the MIL aggregators and pre-training techniques used. Incorporating the suggested

CSC module into the CAMELYON16 dataset led to an average AUC improvement of 4.01% when using ImageNet pre-training and 2.60% when using SimCLR

Table.4: Proposed CSC module parameter selections the number of layer when atoms m = 16

#Layers (L)	FLOPS	AUC
L=2	59.53K	90.61
L=4	70.03K	91.31
L=6	86.13K	92.10
L=8	102.22K	91.27

pre-training. Applying the CSC module to two separate pre-trained feature embeddings also resulted in an average accuracy gain of 2.37% and 3.63%, respectively. We found that utilizing ImageNet pre-training increased AUC on the TCGA-NSCLC dataset by an average of 3.69%, whereas using SimCLR pre-training increased AUC by 2.28%. An accuracy enhancement of 4.01% and 6.63%, respectively, was observed when features derived from the two ResNet-18 models that were pre-trained differently were utilized. In addition, our results revealed that the enhancement in ImageNet pre-training (with an average AUC of 3.85% and an accuracy of 4.50%) was more substantial than that of SimCLR pre-training (with an AUC of 2.44% and an accuracy of 3.82%). This implies that the task of improving high-quality feature embedding, such as SimCLR pre-training, is more difficult compared to developing a low-quality feature embedding, such as ImageNet pre-training. Additionally, it is usually observed that superior feature embedding results in improved performance. Importantly, the suggested CSC module improved performance by 3.85% in AUC and 4.50% in accuracy, equivalent to the SimCLR pretraining (4.21% and 4.98%). However, in contrast to self-supervised pre-training, the proposed CSC module can be seamlessly integrated into existing MIL frameworks without requiring an additional training phase.
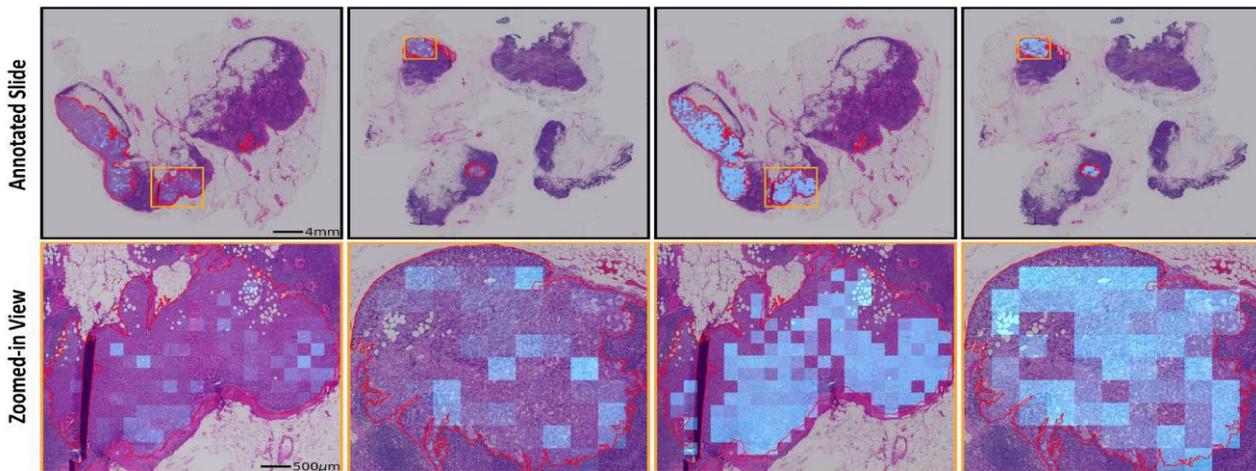
Fig. 2: The tumor localization in CAMELYON16 using the SimCLR pre-trained features: (a) map form ABMIL -Gated w/o CSC and (b) map form ABMIL-Gated w CSC

4.5 ABLATION STUDY

To examine the influence of hyperparameter selection (specifically, the number of layers L and the number of atoms in the dictionary m) on the performance of the CSC module, a sequence of ablation experiments were conducted. Using SimCLR pre-trained features on CAMELYON16, ABMIL-Gated performed ablation investigations. To investigate the influence of the quantity of atoms, we kept the number of layers constant at 6. Increasing the number of atoms resulted in a progressive performance improvement, as well as an increase in parameters and calculation (Table 3). We found that increasing the number of atoms from 16 to 32 improved performance by 0.32% in AUC but increased computation by tenfold. We fixed the number of atoms at 16 to test how layer count affected performance. Increasing the number of layers gradually made the AUC better, but it took more time to do the calculations (Table 4). A decrease in value was noted as L was raised from 2 to 4, potentially attributable to slight variations in the convergence trajectory of ISTA-ACC.

4.6 INTERPRETABILITY

In addition to enhancing the performance of numerous MIL aggregators, the proposed CSC module also improved their interpretability. The vanilla Attention-Based Multiple Instance Learning (ABMIL) model demonstrated an imbalanced distribution of attention scores (mean: 0.1780, standard deviation: 0.0748) when applied to the MNIST-bags dataset, specifically for the target digit '9'. (Fig. 1) This unequal distribution can be attributed to the model's lack of understanding regarding the relationships between instances within the dataset. Following the integration of the suggested CSC module, the attention scores for the ABMIL

with CSC became more uniformly distributed (0.1995 ± 0.0341) (Fig. 1). Similar results were noted in the identification of the structure's location inside the designated area of interest in whole slide images (WSIs). The utilization of attention scores allowed for the assessment of the importance of each patch, hence offering valuable insights into critical morphological features that can inform clinical diagnosis. The vanilla ABMIL-Gated model had inadequate tumor localization performance on the CAMELYON16 dataset, as illustrated in Fig. 2, where it failed to accurately identify the majority of tumor patches.

Nevertheless, the incorporation of the CSC module greatly improved the localization accuracy of the ABMIL-Gated model, as depicted in Fig. 2, demonstrating a strong alignment with the annotated tumor shape. The results obtained from analyzing both the MNIST-bags dataset and the WSI dataset demonstrate that the proposed CSC module's coding of instance embeddings is capable of effectively capturing cross-instance similarities. This, in turn, results in improved localization performance.

V.   CONCLUSION

Using Convolutional Sparse Coding learning, we presented a new MIL framework in this paper called CSCMIL. The method being suggested aims to improve both the embedding of instance features and the modeling of cross-instance similarities, all while minimizing the computational load. Significantly, empirical findings from numerous benchmarks spanning diverse tasks have demonstrated that the integration of the proposed CSC module in a plug-and-play fashion can enhance the performance of state-of-the-art MIL approaches. This

method has potential for drug effect prediction, diabetic retinopathy grading, and cancer detection and pathology analysis using histology.

REFERENCES

[1] He, L., Long, L.R., Antani, S.K., & Thoma, G.R. (2012). Histology image analysis for carcinoma detection and grading. Computer methods and programs in biomedicine, 107 3, 538-56 .

[2] Litjens, G.J., Sánchez, C.I., Timofeeva, N., Hermsen, M., Nagtegaal, I.D., Kovacs, I., Hulsbergen - van de Kaa, C., Bult, P., van Ginneken, B., & van der Laak, J.A. (2016). Deep learning as a tool for increased accuracy and efficiency of histopathological diagnosis. Scientific Reports, 6.

[3] Zhou, X., Li, C., Rahaman, M.M., Yao, Y., Ai, S., Sun, C., Wang, Q., Zhang, Y., Li, M., Li, X., Jiang, T., Xue, D., Qi, S., & Teng, Y. (2020). A Comprehensive Review for Breast Histopathology Image Analysis Using Classical and Deep Neural Networks. IEEE Access, 8, 90931-90956.

[4] Kather, J.N., Pearson, A.T., Halama, N., Jäger, D., Krause, J., Loosen, S.H., Marx, A., Boor, P., Tacke, F., Neumann, U.P., Grabsch, H.I., Yoshikawa, T., Brenner, H., Chang-Claude, J., Hoffmeister, M., Trautwein, C., & Luedde, T. (2019). Deep learning can predict microsatellite instability directly from histology in gastrointestinal cancer. Nature Medicine, 25, 1054 - 1056.

[5] Coudray, N., Ocampo, P.S., Sakellaropoulos, T., Narula, N., Snuderl, M., Fenyö, D., Moreira, A.L., Razavian, N., & Tsirigos, A. (2018). Classification and mutation prediction from non–small cell lung cancer histopathology images using deep learning. Nature Medicine, 24, 1559-1567.

[6] Ilse, M., Tomczak, J.M., & Welling, M. (2018). Attention-based Deep Multiple Instance Learning. International Conference on Machine Learning.

[7] Li, B., Li, Y., & Eliceiri, K.W. (2020). Dual-stream Multiple Instance Learning Network for Whole Slide Image Classification with Self-supervised Contrastive Learning. 2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 14313-14323.

[8] Shao, Z., Bian, H., Chen, Y., Wang, Y., Zhang, J., Ji, X., & Zhang, Y. (2021). TransMIL: Transformer based Correlated Multiple Instance Learning for Whole Slide Image Classication. Neural Information Processing Systems.

[9] Zhang, H., Meng, Y., Zhao, Y., Qiao, Y., Yang, X., Coupland, S.E., & Zheng, Y. (2022). DTFD-MIL: Double-Tier Feature Distillation Multiple Instance Learning for Histopathology Whole Slide Image Classification. 2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 18780-18790.

[10] Xiang, J., & Zhang, J. (2023). Exploring Low-Rank Property in Multiple Instance Learning for Whole Slide Image Classification. International Conference on Learning Representations.

[11] Lu, M.Y., Chen, R.J., Wang, J., Dillon, D., & Mahmood, F. (2019). Semi-Supervised Histology Classification using Deep Multiple Instance Learning and Contrastive Predictive Coding. ArXiv, abs/1910.10825.

[12] Li, H., Zhu, C., Zhang, Y., Sun, Y., Shui, Z., Kuang, W., Zheng, S., & Yang, L. (2023). Task-Specific Fine-Tuning via Variational Information Bottleneck for Weakly-Supervised Pathology Whole Slide Image Classification. 2023 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 7454-7463.

[13] Lu, M.Y., Williamson, D.F., Chen, T.Y., Chen, R.J., Barbieri, M., & Mahmood, F. (2020). Data-efficient and weakly supervised computational pathology on whole-slide images. Nature Biomedical Engineering, 5, 555 - 570.

[14] Zhao, Y., Yang, F., Fang, Y., Liu, H., Zhou, N., Zhang, J., Sun, J., Yang, S., Menze, B.H., Fan, X., & Yao, J. (2020). Predicting Lymph Node Metastasis Using Histopathological Images Based on Multiple Instance Learning With Deep Graph Convolution. 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 4836-4845.

[15] Campanella, G., Hanna, M.G., Geneslaw, L., Miraflor, A.P., Werneck Krauss Silva, V., Busam, K.J., Brogi, E., Reuter, V.E., Klimstra, D.S., & Fuchs, T.J. (2019). Clinical-grade computational pathology using weakly supervised deep learning on whole slide images. Nature Medicine, 25, 1301 - 1309.

[16] Feng, J., & Zhou, Z. (2017). Deep MIML Network. AAAI Conference on Artificial Intelligence.

[17] Hou, L., Samaras, D., Kurç, T.M., Gao, Y., Davis, J.E., & Saltz, J. (2015). Patch-Based Convolutional Neural Network for Whole Slide Tissue Image Classification. 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2424-2433.

[18] Lerousseau, M., Vakalopoulou, M., Classe, M., Adam, J., Battistella, E., Carr'e, A., Estienne, T., Henry, T., Deutsch, É., & Paragios, N. (2020). Weakly supervised multiple instance learning histopathological tumor segmentation. International Conference on Medical Image Computing and Computer-Assisted Intervention.

[19] Xu, G., Song, Z., Sun, Z., Ku, C., Yang, Z., Liu, C., Wang, S., Ma, J., & Xu, W. (2019). CAMEL: A Weakly Supervised Learning Framework for Histopathology Image Segmentation. 2019 IEEE/CVF International Conference on Computer Vision (ICCV), 10681-10690.

[20] Wang, X., Yan, Y., Tang, P., Bai, X., & Liu, W. (2016). Revisiting multiple instance neural networks. ArXiv, abs/1610.02501.

[21] Sharma, Y., Shrivastava, A., Ehsan, L., Moskaluk, C.A., Syed, S., & Brown, D.E. (2021). Cluster-to-Conquer: A Framework for End-to-End Multi-Instance Learning for Whole Slide Image Classification. International Conference on Medical Imaging with Deep Learning.

[22] Zhu, Z., Xu, M., Bai, S., Huang, T., & Bai, X. (2019). Asymmetric Non-Local Neural Networks for Semantic Segmentation. 2019 IEEE/CVF International Conference on Computer Vision (ICCV), 593-602.

[23] Zhu, W., Lou, Q., Vang, Y.S., & Xie, X. (2016). Deep Multi-instance Networks with Sparse Label Assignment for Whole Mammogram Classification. bioRxiv.

[24] Gregor, K., & LeCun, Y. (2010). Learning Fast Approximations of Sparse Coding. International Conference on Machine Learning.

[25] Sreter, H., & Giryes, R. (2017). Learned Convolutional Sparse Coding. 2018 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2191-2195.

[26] Mohan, S., Kadkhodaie, Z., Simoncelli, E.P., & Fernandez-Granda, C. (2019). Robust and interpretable blind image denoising via bias-free convolutional neural networks. ArXiv, abs/1906.05478.

[27] Lecouat, B., Ponce, J., & Mairal, J. (2019). Fully Trainable and Interpretable Non-local Sparse Models for Image Restoration. European Conference on Computer Vision.

[28] Liu, S., Li, X., Zhai, Y., You, C., Zhu, Z., Fernandez-Granda, C., & Qu, Q. (2021). Convolutional Normalization: Improving Deep Convolutional Network Robustness and Training. Neural Information Processing Systems.

[29] Dai, X., Li, M., Zhai, P., Tong, S., Gao, X., Huang, S., Zhu, Z., You, C., & Ma, Y. (2022). Revisiting Sparse Convolutional Model for Visual Recognition. ArXiv, abs/2210.12945.

[30] Ehteshami Bejnordi, B., Veta, M., Johannes van Diest, P., van Ginneken, B., Karssemeijer, N., Litjens, G.J., van der Laak, J.A., Hermsen, M., Manson, Q.F., Balkenhol, M.C., Geessink, O.G., Stathonikos, N., van Dijk, M.C., Bult, P., Beca, F., Beck, A.H., Wang, D., Khosla, A., Gargeya, R., Irshad, H., Zhong, A., Dou, Q., Li, Q., Chen, H., Lin, H., Heng, P., Hass, C., Bruni, E., Wong, Q.K., Halici, U., Öner, M.Ü., Cetin-Atalay, R., Berseth, M., Khvatkov, V., Vylegzhanin, A., Kraus, O.Z., Shaban, M., Rajpoot, N.M., Awan, R., Sirinukunwattana, K., Qaiser, T., Tsang, Y., Tellez, D., Annuscheit, J., Hufnagl, P., Valkonen, M., Kartasalo, K., Latonen, L., Ruusuvuori, P., Liimatainen, K., Albarqouni, S., Mungal, B., George, A.A., Demirci, S., Navab, N., Watanabe, S., Seno, S., Takenaka, Y., Matsuda, H., Ahmady Phoulady, H., Kovalev, V.A., Kalinovsky, A., Liauchuk, V., Bueno, G., Fernández-Carrobles, M.D., Serrano, I., Deniz, O., Racoceanu, D., & Venâncio, R. (2017). Diagnostic Assessment of Deep Learning Algorithms for Detection of Lymph Node Metastases in Women With Breast Cancer. JAMA, 318, 2199–2210.

[31] Dietterich, T.G., Lathrop, R.H., & Lozano-Perez, T. (1997). Solving the Multiple Instance Problem with Axis-Parallel Rectangles. Artif. Intell., 89, 31-71.

[32] Tu, M., Huang, J., He, X., & Zhou, B. (2019). Multiple instance learning with graph neural networks. ArXiv, abs/1906.04881.

[33] Yan, Y., Wang, X., Guo, X., Fang, J., Liu, W., & Huang, J. (2018). Deep Multi-instance Learning with Dynamic Pooling. Asian Conference on Machine Learning.

[34] Wang, X., Girshick, R.B., Gupta, A.K., & He, K. (2017). Non-local Neural Networks. 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition, 7794-7803.

Method for Determining Weighting Coefficients in Weighted Taylor Series Applied to Water Wave Modeling

Syawaluddin Hutahaean

Ocean Engineering Program, Faculty of Civil and Environmental Engineering,-Bandung Institute of Technology (ITB), Bandung 40132, Indonesia
syawalf1@yahoo.co.id

Abstract— The Weighted Taylor series is an adaptation of the conventional Taylor series truncated to the first order, wherein high-order differential terms are replaced by introducing weighting coefficients to the initial terms. This study presents a novel approach for computing these weighting coefficients specifically designed for water wave modeling. Subsequently, the derived weighted Taylor series is employed to formulate both weighted continuity and the weighted Laplace equation. The weighted Laplace equation facilitates the formulation of the velocity potential equation, leading to the development of wave transformation equations encompassing important phenomena such as shoaling, breaking, and refraction-diffraction. Additionally, the formulation of the weighted Euler momentum conservation equation is introduced to determine the wave number in deep water. By scrutinizing the outcomes of dispersion equations, as well as analyzing shoaling-breaking and refraction-diffraction scenarios, optimal values for the weighting coefficients are identified..

I. INTRODUCTION

Hydrodynamic equations are commonly expressed through a truncated Taylor series, where terms of order 2 and higher are omitted, reducing the series to include only order 1 differentials. This simplification is based on the assumption that, within small intervals such as, $\delta t, \delta x, \delta z$, the values of second-order terms and beyond become negligible and can be disregarded.

There is a lack of prior research systematically investigating the Taylor series truncation method. Hutahaean (2021) introduced the weighted Taylor series by examining intervals where the values of 1st order terms significantly surpass those of 2nd order terms. Building upon this, Hutahaean (2022) applied the Forward Difference scheme to formulate the weighted Taylor series, assigning a weighting coefficient solely to the time derivative term in the function $f(x, z, t)$. Both studies demonstrated that the

weighting coefficient in the truncated Taylor series can alter wave characteristics, shortening wavelength and reducing water particle velocity. These findings suggest that utilizing a weighted Taylor series with optimized coefficients can enhance water wave models.

In this study, the Taylor series was truncated using the central-difference method. This method only extracts contributions from even-order differential terms, and is subsequently corrected by the remaining contributions from odd-order differential terms.

The truncated Taylor series was then utilized to formulate the foundational equation of hydrodynamics, specifically the continuity equation. Each term in this equation received its respective weighting coefficient, leading to the designation of a weighted continuity equation.

Employing the weighted continuity equation, the formulation of the weighted Laplace Equation followed. Subsequently, the weighted Laplace equation was solved

for sloping bottoms to derive conservation equations governing variations in wave constants as waves transition from deeper to shallower waters.

By utilizing these conservation equations, the study derived equations describing changes in wave constants, including wave amplitude and wavelength in shallower waters. These equations incorporate weighting coefficients, with the corresponding values of the weighting coefficients studied based on the results of dispersion equation, shoaling breaking model, and refraction-diffraction model.

II.   WEIGHTED TAYLOR SERIES

Taylor series for a function with two variables, $f = f(x,t)$, (Arden, Bruce W. and Astill Kenneth N. ,1970)   is

$$f(x + \delta x, t + \delta t) = f(x,t) + + \delta t \frac{\mathrm{d}f}{\mathrm{d}t} +$$

$$\delta x \frac{\mathrm{d}f}{\mathrm{d}x} \quad \frac{\delta t^2}{2!} \frac{\mathrm{d}^2 f}{\mathrm{d}t^2} + \delta t \delta x \frac{\mathrm{d}^2 f}{\mathrm{d}t \mathrm{d}x} + \frac{\delta x^2}{2!} \frac{\mathrm{d}^2 f}{\mathrm{d}x^2} + \cdots \quad (1)$$

In this paper, x represents the horizontal axis, z the vertical axis, and t time. In the formulation of hydrodynamic equations, including continuity equation and Euler's momentum conservation equation, this Taylor series is truncated to a first-order differential series, assuming that within the interval δt, δx are very small, higher-order differential terms are very small and can be neglected, i.e., it becomes:.

$$f(x + \delta x, z + \delta z, t + \delta t) = f(x,z,t) + \delta t \frac{\mathrm{d}f}{\mathrm{d}t} + \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

However, as the interval decreases, not only do the values of higher-order differential terms decrease, but the values of first-order terms also decrease. As a result, the relative values of higher-order terms to the first-order terms remain significant.

Equation (1) can be written as follows,

$$f(x + \delta x, t + \delta t) = f(x,t) +$$
$$\left(1 + \frac{\delta t}{2} \frac{\mathrm{d}}{\mathrm{d}t} + \delta x \frac{\mathrm{d}}{\mathrm{d}x} + ..\right) \delta t \frac{\mathrm{d}f}{\mathrm{d}t}$$
$$+ \left(1 + \frac{\delta x}{2} \frac{\mathrm{d}}{\mathrm{d}x} + ..\right) \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

There are contributions from higher-order terms to the first-order terms. Therefore, these higher-order terms cannot be simply neglected. Truncating the series to the first order should be accompanied by providing coefficients that represent the higher-order terms.

$$f(x + \delta x, z + \delta z, t + \delta t) = f(x,z,t)$$
$$+ \gamma_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t} + \gamma_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

This series is a weighted Taylor series, with weighting coefficients γ_t and γ_x. With this equation, the role of higher-order terms is not completely eliminated; it is represented by the weighting coefficients. The characteristics of the function present in the higher-order terms are still reflected in the weighting coefficients.

The aim of this research is to develop a method for calculating weighting coefficients by extracting contributions from higher-order terms and adding them to the first-order terms.

The method of absorbing contributions from high-order terms or the formation of weighting coefficients generally consists of two parts:
a.   Absorbing contributions from odd-order differential terms.
b.   Absorbing contributions from even-order differential terms.

In this research, weighting coefficients will be formulated for the water wave modeling equation. The solution to the velocity potential equation of the Laplace equation (Dean (1991)) is:

$$\phi(x,z,t) = G \cos kx \cosh k(h+z) \sin \sigma t$$

k is wave number, $k = \frac{2\pi}{L}$, σ is the angular frequency, $\sigma = \frac{2\pi}{T}$, T is wave period and h is water depth. Considering that sin function has similar characteristics to the cos function, a method for calculating weighting coefficients will be developed using a functional form.,

$$f(x,z,t) = \cos kx \cosh k(h+z) \cos \sigma t$$

III.   ABSORPTION OF CONTRIBUTIONS FROM THIRD-ORDER DIFFERENTIAL TERMS

In this research, a calculation method is developed wherein the Taylor series is employed up to the third order only. Limitations are introduced by utilizing an interval size where terms of the fourth order and higher become negligible. Subsequently, the third-order terms are removed from the series, and their values are added to the first-order terms. The magnitude of the contribution of third-order terms to the first-order terms is expressed with a contribution coefficient.

The contribution coefficient for the time differential terms is given by,

$$\mu_t = \frac{\frac{\delta t^3}{6} \frac{\mathrm{d}^3 f}{\mathrm{d}t^3}}{\delta t \frac{\mathrm{d}f}{\mathrm{d}t}}$$

As a function of time t is $f(t) = \cos \sigma t$, the differential substitution of this function, performed under the condition $\cos \sigma t = \sin \sigma t$

$$\mu_t = -\frac{\delta t^2}{6}\sigma^2$$

Substituting $\delta t = \varepsilon_t T$ and $\sigma = \frac{2\pi}{T}$,

$$\mu_t = -\frac{4\pi^2}{6}\varepsilon_t^2$$

ε_t is the time interval coefficient t. Similarly, for the function $f(x) = \cos kx$, the following is obtained

$$\mu_x = -\frac{4\pi^2}{6}\varepsilon_x^2$$

ε_x is the coefficient of the interval x, where $\delta x = \varepsilon_x L$, and

$$\mu_z = \frac{4\pi^2}{6}\varepsilon_z^2$$

ε_z is the coefficient of the interval z, where $\delta z = \varepsilon_z L$.

It is important to note that the computation of contribution coefficients necessitates values for the interval coefficients ε_t, ε_x and ε_z which will be discussed in the subsequent section.

3.1.   Calculation of Interval Coefficients

In this section, the method of calculating the values of interval coefficients ε_t, ε_x and ε_z, is discussed. The calculation is performed using the optimization equation.

$$\left|\frac{s_2+s_3}{s_1}\right| \leq \varepsilon \qquad\qquad\qquad ....(2)$$

s_1, s_2 dan s_3, are, in order, the first, second, and third terms in the Taylor series. Term 1 is a term with a first-order differential, term 2 is a term with a second-order differential, and term 3 is a term with a third-order differential.

ε is a small number whose value is determined. The larger the value of ε, the larger the values of higher-order terms that will be extracted. Furthermore, ε is referred to as the optimization coefficient..

The optimization equation is an equation with variables representing the size of the interval, i.e., $\delta t, \delta x, \delta z$. This equation for the interval size is converted into an equation for the interval coefficients, i.e., ε_t, ε_x and ε_z, by substituting $\delta t = \varepsilon_t T$, $\delta x = \varepsilon_x L$ dan $\delta z = \varepsilon_z L$. T is the wave period, and L is the wavelength.

a.   Calculation of Time Interval Coefficient at $-t$ ε_t in the function $f(t) = \cos \sigma t$.

By utilizing a series up to order 3, the optimization equation can be expressed as,

$$\left|\frac{\frac{\delta t^2 d^2 f}{2\ dt^2}+\frac{\delta t^3 d^3 f}{6\ dt^3}}{\delta t \frac{df}{dt}}\right| = \varepsilon$$

Substituting the differentials of $f(t)$ when $\cos \sigma t = \sin \sigma t$, a second-degree polynomial for δt is obtained.

$$\frac{\delta t}{2}\sigma - \frac{\delta t^2}{6}\sigma^2 = \varepsilon$$

Substituting $\delta t = \varepsilon_t T$, and $\sigma = \frac{2\pi}{T}$, where T is wave period,

$$\frac{2\pi^2}{3}\varepsilon_t^2 - \pi\varepsilon_t + \varepsilon = 0$$

Of the two ε_t, the least value is used.

In the equation for ε_t there are neither variable σ or T. Hence, ε_t is not dependent to the wave period T and it applies to any wave period T.

b.   Interval Coefficient $-x$ ε_x on function $f(x,t) = \cos \sigma t \cos kx$.

For this function, there will be two variables in the optimization equation ε_t and ε_x. By using ε_t from the calculation results for the function $f(t) = \cos \sigma t$, hence ε_x is the only unknown variable.

The optimization equation for the function $f(x,t)$ is worked out using the Taylor series up to the third term, resulting in a third-degree polynomial. This polynomial can be solved using the Newton-Rhapson iteration method, which requires an initial iteration value. To obtain the initial iteration value, the optimization equation is first solved using only the second-order differential terms, forming a quadratic polynomial..

$$\left|\frac{s_2}{s_1}\right| \geq \varepsilon.$$

Where

$$s_1 = \delta t \frac{df}{dt} + \delta x \frac{df}{dx}$$

$$s_2 = \frac{\delta t^2}{2}\frac{d^2 f}{dt^2} + \delta t \delta x \frac{d^2 f}{dt dx} + \frac{\delta x^2}{2}\frac{d^2 f}{dx^2}$$

Substituting s_1 and s_2 into the optimization equation, the computation proceeds under the conditions $\cos \sigma t = \sin \sigma t$ and $\cos kx = \sin kx$, resulting in the cancellation of terms in the numerator and denominator. Subsequently, the substitution $\delta t = \varepsilon_t T$, $\delta x = \varepsilon_x L$, $\sigma = \frac{2\pi}{T}$ and $k = \frac{2\pi}{L}$ with ε_t as a known variable, a quadratic equation in ε_t is derived from calculations involving the function $f(t) = \cos \sigma t$

$$c_0 + c_1\varepsilon_x + c_2\varepsilon_x^2 = 0$$
$$c_0 = 2\pi\varepsilon_t\varepsilon - 2\pi^2\varepsilon_t^2$$
$$c_1 = 2\pi\varepsilon + 4\pi^2\varepsilon_t$$
$$c_2 = -2\pi^2$$

The quadratic equation yields two roots, of which the larger one is selected. Notably, the ε_x \ equation no longer contains the wave period T or wavelength L.

Proceeding to the optimization equation (2), we obtain a cubic polynomial.

$$s_3 = \frac{\delta t^3}{6}\frac{d^3 f}{dt^3} + \frac{\delta t^2}{2}\delta x \frac{d^3 f}{dt^2 dx} + \delta t \frac{\delta x^2}{2}\frac{d^3 f}{dt dx^2}$$
$$+ \frac{\delta x^3}{6}\frac{d^3 f}{dx^3}$$

Where,

$$c_0 + c_1 \varepsilon_x + c_2 \varepsilon_x^2 + c_3 \varepsilon_x^3 = 0$$

$$c_0 = 2\pi\varepsilon_t\varepsilon - 2\pi^2\varepsilon_t^2 + \frac{8\pi^3}{6}\varepsilon_t^3$$

$$c_1 = 2\pi\varepsilon + 4\pi^2\varepsilon_t + \frac{8\pi^3}{2}\varepsilon_t^2$$

$$c_2 = -2\pi^2 + \frac{8\pi^3}{2}\varepsilon_t$$

$$c_3 = \frac{8\pi^3}{6}$$

The solution to this equation can be determined using the Newton-Rhapson iteration method, initiating the process with the root derived from the quadratic equation.

c. Interval coefficient $-z$ ε_z for the function $f(x,z,t) = \cos\sigma t\cos kx\cosh k(h+z)$.

The equation for calculating ε_z is formulated using a method similar to the equations used to calculate ε_t and ε_x, namely by utilizing optimization equations. By applying conditions such as $\text{ccos}\,\sigma t = \sin\sigma t$, $\cos kx = \sin kx$ dan $\cosh k(h+z) = \sinh k(h+z)$, specifically when h is large and z is very small, the elements in the numerator and denominator cancel each other out. Substituting $\delta t = \varepsilon_t L$, $\delta x = \varepsilon_x L$, $\delta z = \varepsilon_z L$, $\sigma = \frac{2\pi}{T}$ and $k = \frac{2\pi}{L}$, we obtain an equation with three variables: ε_t, ε_x and ε_z, with ε_t and ε_x obtained from previous calculations, one variable, and ε_z remains.

The quadratic equation for ε_z is,

$$c_{0,2} + c_{1,2}\varepsilon_z + c_{2,2}\varepsilon_z^2 = 0$$

$$c_{0,2} = (\varepsilon_t + \varepsilon_x)2\pi\varepsilon - 2\pi^2\varepsilon_t^2 + 4\pi^2\varepsilon_t\varepsilon_x - 2\pi^2\varepsilon_x^2$$

$$c_{1,2} = -2\pi\varepsilon - 4\pi^2\varepsilon_t - 4\pi^2\varepsilon_x$$

$$c_{2,2} = 2\pi^2$$

This quadratic equation yields two values for ε_z, with the larger value chosen for subsequent analysis. These solutions form the input for a third-degree equation.

$$c_{0,3} = \frac{8\pi^3}{6}\varepsilon_t^3 + \frac{8\pi^3}{2}\varepsilon_x\varepsilon_t^2 + \frac{8\pi^3}{2}\varepsilon_t\varepsilon_x^2 + \frac{8\pi^3}{6}\varepsilon_x^3$$

$$c_0 = c_{0,1} + c_{0,2}$$

$$c_{1,3} = -\frac{8\pi^3}{2}\varepsilon_t^2 + 8\pi^3\varepsilon_t\varepsilon_x - \frac{8\pi^3}{2}\varepsilon_x^2$$

$$c_1 = c_{1,2} + c_{1,3}$$

$$c_{2,3} = -\frac{8\pi^3}{2}\varepsilon_t - \frac{8\pi^3}{2}\varepsilon_x$$

$$c_2 = c_{2,2} + c_{2,3}$$

$$c_3 = \frac{8\pi^3}{6}$$

$c_{0,2}$, $c_{1,2}$ and $c_{2,2}$ are derived from the quadratic equations..

Table (1) below showcases examples of interval coefficient calculation results for various optimization coefficient value ε .

Table 1. The values of interval coefficients

ε	ε_t	ε_x	ε_z
0.005	0.0016	0.00478	0.01452
0.006	0.00192	0.00574	0.01747
0.007	0.00224	0.0067	0.02044
0.008	0.00256	0.00766	0.02342
0.009	0.00288	0.00862	0.02641
0.01	0.00321	0.00959	0.02942

As seen in Table 1, as the value of ε increases, the interval coefficient also increases, indicating a greater contribution from higher-order terms. With these interval coefficients, the contribution coefficients of the higher-order terms are calculated.

Table 2: The values of the contribution coefficients.

ε	μ_t	μ_x	μ_z
0.005	-0.000017	-0.000151	0.001388
0.006	-0.000024	-0.000217	0.002009
0.007	-0.000033	-0.000296	0.002750
0.008	-0.000043	-0.000386	0.003611
0.009	-0.000055	-0.000489	0.004596
0.010	-0.000068	-0.000604	0.005705

IV. CONTRIBUTION FROM EVEN DIFFERENTIAL TERMS

In this stage, the Taylor series is calculated with a very small interval size, so the fourth-order terms and higher are very small, while the third-order term has been absorbed by adding its value to the first-order term. Thus, the remaining Taylor series of the second order takes the form,

$$f(x+\delta x, t+\delta t) = f(x,z,t) + (1+\mu_t)\delta t\frac{df}{dt} + (1+\mu_x)\delta x\frac{df}{dx} + \frac{\delta t^2}{2}\frac{d^2f}{dt^2} + \delta t\,\delta x\frac{d^2f}{dt\,dx} + \frac{\delta x^2}{2}\frac{d^2f}{dx^2}$$

The simplification of the subsequent expressions is as follows.

$$\alpha_t = 1 + \mu_t$$
$$\alpha_x = 1 + \mu_x$$

Truncated Taylor series becomes

$$f(x+\delta x, t+\delta t) = f(x,z,t) + \alpha_t\delta t\frac{df}{dt}$$

$$+\alpha_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x} + \frac{\delta t^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}t^2} + \delta t\,\delta x\frac{\mathrm{d}^2 f}{\mathrm{d}t\mathrm{d}x} + \frac{\delta x^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}x^2}$$

This simplification involves the absorption of contributions from even higher-order differential terms through the application of the Central Different Method operation.

4.1. Function $f(x,t)$

Truncated Taylor series for $(x+\delta x, t+\delta t)$

$$f(x+\delta x, t+\delta t) = f(x,z,t) + \alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t} +$$

$$\alpha_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x} + \frac{\delta t^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}t^2} + \delta t\,\delta x\frac{\mathrm{d}^2 f}{\mathrm{d}t\mathrm{d}x} + \frac{\delta x^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}x^2}$$

Truncated Taylor series for $(x-\delta x, t-\delta t)$

$$f(x-\delta x, t-\delta t) = f(x,z,t) - \alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t} -$$

$$\alpha_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x} + \frac{\delta t^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}t^2} + \delta t\,\delta x\frac{\mathrm{d}^2 f}{\mathrm{d}t\mathrm{d}x} + \frac{\delta x^2}{2}\frac{\mathrm{d}^2 f}{\mathrm{d}x^2}$$

These two equations are subtracted from each other,

$$f(x+\delta x, t+\delta t) - f(x-\delta x, t-\delta t)$$
$$= 2\alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t} + 2\alpha_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

During this operation, the even higher-order differential terms automatically vanish. $\frac{\mathrm{d}f}{\mathrm{d}t}$ will be absorbed at $\frac{\mathrm{d}f}{\mathrm{d}x}$, and the last equation is divided by $2\delta x$,

$$\frac{f(x+\delta x, t+\delta t) - f(x-\delta x, t-\delta t)}{2\delta x}$$
$$= \alpha_t \frac{\delta t}{\delta x}\frac{\mathrm{d}f}{\mathrm{d}t} + \alpha_x \frac{\mathrm{d}f}{\mathrm{d}x}$$

For very small values of δt and δx, this equation becomes a total spatial differential,

$$\frac{Df}{dx} = \alpha_t \frac{\delta t}{\delta x}\frac{\mathrm{d}f}{\mathrm{d}t} + \alpha_x \frac{\mathrm{d}f}{\mathrm{d}x}$$

The Taylor series, which has eliminated both even and odd-order differential terms, is,

$$f(x+\delta x, t+\delta t) = f(x,z,t) + \alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t}$$
$$+\alpha_t \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

Substituting the total spatial differential into $\frac{\mathrm{d}f}{\mathrm{d}x}$,

$$f(x+\delta x, t+\delta t) = f(x,t) + \alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t} + \alpha_t \delta x$$
$$\left(\alpha_t \frac{\delta t}{\delta x}\frac{\mathrm{d}f}{\mathrm{d}t} + \alpha_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x}\right)$$

$$f(x+\delta x, t+\delta t) = f(x,t) + (1+\alpha_x)\alpha_t \delta t \frac{\mathrm{d}f}{\mathrm{d}t}$$
$$+\alpha_x^2 \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

This equation is written as,

$$f(x+\delta x, t+\delta t) = f(x,t) + \gamma_{t,2}\delta t \frac{\mathrm{d}f}{\mathrm{d}t} + \gamma_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x}$$

This equation represents a weighted Taylor series for the function $f = f(x,t)$ with weighting coefficients,

$$\gamma_{t,2} = (1+\alpha_x)\alpha_t$$
$$\gamma_x = \alpha_x^2$$

The use of the index 2 in $\gamma_{t,2}$ indicates that the weighting coefficient is for a function with two variables, $f = f(x,t)$. The cross-contribution, i.e., the contribution of spatial derivative to the time derivative, is present in $\alpha_x \alpha_t$. In cases where contribution coefficients are negligible, where μ_t and μ_x are both zero, resulting in $\alpha_t = \alpha_x = 1$, we obtain $\gamma_{t,2} = 2$ and $\gamma_x = 1$, these values serve as the fundamental weighting coefficients for the function $f(x,t)$.

4.2. Function with three variables $f = f(x,z,t)$.

To obtain the contribution of even-order differential terms for a function with three variable $f = f(x,z,t)$, the total spatial derivative $\frac{Df}{dx}$ from the function with two variables $f = f(x,t)$ and $\frac{Df}{dz}$ on the function $f = f(z,t)$ where the formulation of $\frac{Df}{dz}$ is performed in the same method as the formulation of $\frac{Df}{dx}$, obtaining

$$\frac{Df}{dz} = \alpha_t \frac{\delta t}{\delta z}\frac{\mathrm{d}f}{\mathrm{d}t} + \alpha_z \frac{\mathrm{d}f}{\mathrm{d}z}$$

$\frac{Df}{dx}$ and $\frac{Df}{dz}$ is substituted into $\frac{\mathrm{d}f}{\mathrm{d}x}$ and $\frac{\mathrm{d}f}{\mathrm{d}z}$ on the Taylor Series $f = f(x,z,t)$ which has eliminated its higher-order terms, we obtain

$$f(x+\delta x, z+\delta z, t+\delta t) = f(x,z,t) + \gamma_{t,3}\delta t \frac{\mathrm{d}f}{\mathrm{d}t}$$
$$+\gamma_x \delta x \frac{\mathrm{d}f}{\mathrm{d}x} + \gamma_z \delta z \frac{\mathrm{d}f}{\mathrm{d}z}$$

$$\gamma_{t,3} = (1+\alpha_x+\alpha_z)\alpha_t$$
$$\gamma_x = \alpha_x^2$$
$$\gamma_z = \alpha_z^2$$

It is observed that the value of γ_x on $f(x,z,t)$ is the same as the value of γ_x for the function $f(x,t)$. In cases where contribution coefficients are neglected, where $\mu_t = \mu_x = \mu_z = 0$ resulting in $\alpha_t = \alpha_x = \alpha_z = 1$, we obtain $\gamma_{t,3} = 3$, while $\gamma_x = \gamma_z = 1$. These values serve as the fundamental weighting coefficients for the function $f(x,z,t)$.

The values of weighting coefficients for various values of ε are presented in Table (3).

Table 3:. The values of weighting coefficients.

ε	$\gamma_{t,2}$	$\gamma_{t,3}$	γ_x	γ_z
0.005	1.99990	3.00237	0.9994	1.00556
0.006	1.99986	3.00344	0.99913	1.00805
0.007	1.99980	3.00471	0.99882	1.01103
0.008	1.99974	3.00619	0.99846	1.01450

| 0.009 | 1.99967 | 3.00789 | 0.99804 | 1.01847 |
| 0.01 | 1.99960 | 3.00980 | 0.99758 | 1.02295 |

It is evident that the values of the weighting functions are not significantly different from the fundamental values, namely $\gamma_{t,2} = 2.0$, $\gamma_{t,3} = 3.0$, $\gamma_x = 1.0$ and $\gamma_z = 1.0$. However, to satisfy a balance equation, it is advisable to use accurate values for the weighting coefficients.

As ε increases, the values of $\gamma_{t,2}$ and γ_x, decrease, while $\gamma_{t,3}$ and γ_z increase. Considering that higher-order terms contain information about the function's characteristics, it is preferable to choose ε such that the coefficients. To obtain the optimal ε coefficient, precise calibration of the model results formulated using the weighted Taylor series is necessary. In the modeling of water wave transformation, this calibration can be applied to evaluate the breaker height or breaker depth generated by the model.

V.   THE APPLICATION ON WATER WAVE MODELING

The formulation of various equations in this paper is not provided in detail; only the final results are presented. The research focus is on the weighting coefficients.

5.1. Weighted Laplace Equation and its Solution

a. Weighted Laplace Equation

The continuity equation formulated using the weighted Taylor series takes the form of a weighted continuity equation,

$$\gamma_x \frac{\mathrm{d}u}{\mathrm{d}x} + \gamma_z \frac{\mathrm{d}w}{\mathrm{d}z} = 0 \qquad \text{……...(3)}$$

$u(x, z, t)$ is the horizontal water particle velocity, and $w(x, z, t)$ is the vertical water particle velocity. The weighted continuity equation cannot be expressed as

$$\frac{\gamma_x}{\gamma_z} \frac{\mathrm{d}u}{\mathrm{d}x} + \frac{\mathrm{d}w}{\mathrm{d}z} = 0$$

Nor

$$\frac{\mathrm{d}u}{\mathrm{d}x} + \frac{\gamma_z}{\gamma_x} \frac{\mathrm{d}w}{\mathrm{d}z} = 0$$

since it yields different solutions from (3). Therefore, it can be said that γ_x s directly related to $\frac{\mathrm{d}u}{\mathrm{d}x}$ and γ_z is directly related to $\frac{\mathrm{d}w}{\mathrm{d}z}$.

Substituting the velocity potential properties, $u = -\frac{\mathrm{d}\phi}{\mathrm{d}x}$ and $w = -\frac{\mathrm{d}\phi}{\mathrm{d}z}$, into the weighted continuity equation, the weighted Laplace equation is obtained,

$$\gamma_x \frac{\mathrm{d}^2\phi}{\mathrm{d}x^2} + \gamma_z \frac{\mathrm{d}^2\phi}{\mathrm{d}z^2} = 0 \qquad \text{……….(4)}$$

This equation is referred to as the weighted Laplace equation.

b. Solution of the Weighted Laplace Equation

The solution of (4), obtained using the separation of variable method and working with the kinematic bottom boundary condition for a sloping bottom, results in the velocity potential equation,

$$\phi(x, z, t) = G\beta(z) \cos k_x x \sin \sigma t +$$
$$G\beta(z) \sin k_x x \sin \sigma t$$

In this equation, there are two wave numbers: the wave number in the horizontal axis\

$k_x = \frac{k}{\sqrt{\gamma_x}}$, the wavelength in the horizontal axis $L_x = \frac{2\pi}{k_x}$ and the wave number in the vertical axis $k_z = \frac{k}{\sqrt{\gamma_z}}$, the wavelength in the vertical axis $L_z = \frac{2\pi}{k_z}$.

$$\beta(z) = \frac{\alpha e^{k_z(z+h)} + e^{-k_z(z+h)}}{2}$$

$$\beta_1(z) = \frac{\alpha e^{k_z(z+h)} - e^{-k_z(z+h)}}{2}$$

$$\alpha = \frac{\frac{1}{\sqrt{\gamma_z}} + \frac{1}{\sqrt{\gamma_x}} \frac{dh}{dx}}{\frac{1}{\sqrt{\gamma_z}} - \frac{1}{\sqrt{\gamma_x}} \frac{dh}{dx}}$$

$\frac{dh}{dx}$ is the bottom slope, which is negative for waves moving from deep water to shallow water..

On $\alpha = 1$, $\beta(z) = \cosh k_z(h + z)$; $\beta_1(z) = \sinh k_z(h + z)$

c. Equation for G

The equation for G is obtained by integrating the weighted Kinematic Free Surface Boundary Condition with respect to time (Hutahaean (2023b),

$$G = \frac{\sigma \gamma_{t,2} A}{2k \left(\frac{1}{\sqrt{\gamma_z}} - \frac{kA}{2} \right) \beta(\theta\pi)}$$

$$\beta(\theta\pi) = \frac{\alpha e^{\theta\pi} + e^{-\theta\pi}}{2}$$

θ is the deep water coefficient, where $\frac{\beta_1(\theta\pi)}{\beta(\theta\pi)} = 1$. In this research, $\theta = 1.95$. In the analysis of shoaling-breaking, this coefficient plays a role in determining the breaker depth. A larger θ corresponds to a deeper breaker depth, while a smaller θ results in a shallower breaker depth.

d. Wave Amplitude Function

The equation for G can be expressed as the wave amplitude function,

$$A = \frac{2Gk}{\sigma \gamma_{t,2}} \beta(\theta\pi) \left(\frac{1}{\sqrt{\gamma_z}} - \frac{kA}{2} \right)$$

d. Water Surface Elevation Equation

$$\eta(x,t) = A \cos k_x x \cos \sigma t$$

e.   Wave Number Conservation Equation

$$\frac{dk \left(h + \frac{A}{2} \right)}{dx} = 0$$

f.   Energy Conservation Equation

$$G \frac{\mathrm{d}k}{\mathrm{d}x} + 2k \frac{\mathrm{d}G}{\mathrm{d}x} = 0$$

5.2. Dispersion Equation

By using the weighted Taylor series, and by using the conditions in the formulation of the continuity equation where in a control volume the horizontal velocity only changes on the horizontal axis and the vertical velocity only changes on the vertical axis, and by working on Newton's principle of conservation of momentum we obtain two equations momentum, namely the momentum equation in the horizontal direction and the momentum equation in the vertical direction, respectively, are,

$$\gamma_{t,3} \frac{\mathrm{d}u}{\mathrm{d}t} + \gamma_x u \frac{\mathrm{d}u}{\mathrm{d}x} = -\frac{1}{\rho} \frac{\mathrm{d}p}{\mathrm{d}x}$$

$$\gamma_{t,3} \frac{\mathrm{d}w}{\mathrm{d}t} + \gamma_{z,3} w \frac{\mathrm{d}w}{\mathrm{d}z} = -\frac{1}{\rho} \frac{\mathrm{d}p}{\mathrm{d}z} - g$$

The vertical momentum equation is expressed as the integration of the pressure equation $\frac{\mathrm{d}p}{\mathrm{d}z}$, over the water depth. By employing surface dynamic boundary conditions $p_\eta = 0$, the pressure equation p is obtained. Subsequently, differentiating the pressure equation with respect to the horizontal axis and substituting it into the horizontal momentum equation, we apply this at $z = \eta$ to yield the surface momentum equation.

$$\gamma_{t,3} \frac{\mathrm{d}u_\eta}{\mathrm{d}t} + \frac{\gamma_x}{2} \frac{\mathrm{d}u_\eta u_\eta}{\mathrm{d}x} = -g \frac{\mathrm{d}\eta}{\mathrm{d}x}$$

The dispersion equation is obtained by utilizing the surface momentum equation while disregarding the convective acceleration term,

$$\gamma_{t,3} \frac{\mathrm{d}u_\eta}{\mathrm{d}t} = -g \frac{\mathrm{d}\eta}{\mathrm{d}x}$$

Substituting the velocity potential by employing its inherent property and substituting the water surface equation and the wave amplitude function, the dispersion equation is derived,,

$$\frac{gA}{2} k^2 - \frac{g}{\sqrt{\gamma_z}} k + \gamma_{t,2} \gamma_{t,3} \sigma^2 = 0$$

This dispersion equation is solely for the calculation of wave numbers in deep water. To determine wave numbers in shallow water, the shoaling-breaking model is utilized..

5.3. Shoaling Breaking Equations

By working on the conservation equations, the G dan wave amplitude function (Hutahaean (…)), he shoaling-breaking equations are derived. For waves transitioning from x to $x + \delta x$,

$$\frac{\mathrm{d}k}{\mathrm{d}x} = -\frac{4k}{(4h + 3A)} \frac{dh}{dx}$$

$$k_{x+\delta x} = k_x + \delta x \frac{\mathrm{d}k}{\mathrm{d}x}$$

$$\frac{\mathrm{d}A}{\mathrm{d}x} = \frac{G}{\sigma \gamma_{t,2}} \frac{\mathrm{d}k}{\mathrm{d}x} \left(\frac{1}{\sqrt{\gamma_z}} - \frac{kA}{2} \right) \beta(\theta\pi)$$

$$A_{x+\delta x} = A_x + \delta x \frac{\mathrm{d}A}{\mathrm{d}x}$$

$$G_{x+\delta x} = e^{\ln G_x - \frac{1}{2}(\ln k_{x+\delta x} - \ln k_x)}$$

5.4. Refraction-Diffraction Equations

The shoaling-breaking equations can be transformed into refraction-diffraction equations using the procedure outlined by Hutahaean (2023a).

VI.   OUTCOMES OF THE MODEL

a.   The Results of Dispersion Equations

In the following section, the computed wavelengths for waves with a period of 8 seconds are presented. The wave amplitude A varies, with the wave height $H = 2A$. An optimization coefficient of $\varepsilon = 0.01$ where $\gamma_{t,2} = 1.99960$, $\gamma_{t,3} = 3.00980$, $\gamma_x = 0.99758$, $\gamma_z = 1.02295$.. The calculated results are summarized in Table (4) as follows.

Table 4: Wavelength from the modelling outcome

H (m)	L (m)	L_x (m)	L_z (m)	$\frac{H}{L_x}$
2	12.132	12.117	12.264	0.165
2.1	11.784	11.77	11.912	0.178
2.2	11.398	11.384	11.523	0.193
2.3	10.959	10.946	11.078	0.21
2.4	10.434	10.422	10.548	0.23
2.5	9.739	9.727	9.845	0.257

The calculation results for the wavelengths reveal the presence of two wavelengths: the horizontal wavelength L_x

and the vertical wavelength L_z, both exhibiting small differences.

Furthermore, it is observed that within one wave period, the wavelength decreases as the wave height increases, exhibiting different wave steepness. The critical wave steepness according to Michell (1893) is 0.142. The critical wave steepness according to Toffoli, A., Babanin, A., Onaroto, M., and Wased, T. (2010) is 0.170, potentially reaching 0.200. The model results closely align with the critical wave steepness from Toffoli et al., specifically at wave heights of 2.1-2.3 m.

In conclusion, the critical wave steepness from Michell (1893) and Toffoli et al. (2010) indicates the maximum wave height for a given wave period under undisturbed conditions, specifically in deep water. Referring to Toffoli et al.'s criteria, the maximum wave height for waves with a period of 8.0 sec. is expected to be 2.30 m. However, in this study, the maximum wave height for a wave period of 8.0 sec. is found to be 2.50 m, with a wave steepness of 0.257. The relationship between wave period and wave height, according to Wiegel (1949, 1964), is expressed as,

$$H = \frac{gT^2}{15.6^2}$$

For waves with a period of 8.0 sec., the calculated value is $H = 2.58 \ m$.. In this case, the model results closely match the Wiegel (1949, 1964) equation with $\varepsilon = 0.01$.

b.   The outcomes of shoaling breaking modelx

The shoaling-breaking model is applied to waves with an amplitude $A = 1.20$ m in coastal waters with a bottom slope $\frac{dh}{dx} = -0.005$, considering various values of ε and a deep water coefficient $\theta = 1.95$.. The wave period is calculated using the Wiegel (1949, 1964) equation:

$$T = 15.6\sqrt{\frac{H}{g}} \quad (sec)$$

Given a wave amplitude $A = 1.20$ m, $H = 2.40 \ m$, the $T = 7.716$ sec is obtained.

According to Komar, Paul D., and Gaughan, Michael K. (1968), the breaker height is

$H_b = 0.39 \ g^{1/5}(TH_0)^{2/5}$ m.

H_0 is the deep water wave height. For waves with $H_0 = 2.40 \ m, T = 7.716$ sec the Komar-Gaughan equation yields $H_b = 2.809 \ m$. In Table (6), on $\varepsilon = 0.01$, $H_b = 2.812 \ m$.

Table 6:Breaking conditions for various values ε

ε	H_b (m)	h_b (m)	$L_{x,b}$ (m)	$\frac{H_b}{L_{x,b}}$	$\frac{H_b}{h_b}$
0.005	2.883	3.619	4.539	0.635	0.797
0.006	2.876	3.615	4.532	0.635	0.796
0.007	2.866	3.607	4.521	0.634	0.794
0.008	2.854	3.6	4.509	0.633	0.793
0.009	2.837	3.588	4.491	0.632	0.791
0.01	2.812	3.568	4.46	0.631	0.788

The results of the breaking conditions for various values of ε are presented in Table (6). From $\varepsilon = 0.005$ to $\varepsilon = 0.01$, the breaking conditions vary only in the third decimal place, with $\delta\varepsilon$ changing by 0.001. However, the difference between the breaking conditions with $\varepsilon = 0.005$ and $\varepsilon = 0.01$ is quite significant.

The breaker depth index from the model is $\frac{H_b}{h_b} = 0.788$, which closely aligns with Mc. Cowan's (1894) criterion of $\frac{H_b}{h_b} = 0.78$. However, the most influential factors in determining the breaker depth and breaker depth index are the deep water coefficient θ, the larger θ, the smaller the breaker depth index. The contribution coefficient only corrects the third decimal place. In Table (6), the breaker depth index is obtained using $\theta = 1.95$.

The smallest breaker steepness $\frac{H_b}{L_{x,b}}$ is 0.631, achieved at $\varepsilon = 0.01$. This breaker steepness is significantly larger than the critical wave steepness from both Michell (1893) and Toffoli et al. (2010). This is because the breaker steepness occurs in regions of high wave energy concentration.

Breaking occurs when $\left(\frac{1}{\sqrt{\gamma_z}} - \frac{kA}{2}\right) = 0$,

$$\frac{kA}{2} = \frac{1}{\sqrt{\gamma_z}}$$

Considering $k_x = \frac{k}{\sqrt{\gamma_x}}$ or $k = k_x\sqrt{\gamma_x}$ and $k_x = \frac{2\pi}{L_x}$ the following is obtained,

$$\frac{H_b}{L_{x,b}} = \frac{2}{\pi\sqrt{\gamma_x}\sqrt{\gamma_z}}$$

Hence, the breaking characteristics are determined by the coefficients of the truncated Taylor series. The smaller γ_x and γ_z then the higher the critical wave steepness $\frac{H_b}{L_{x,b}}$, making breaking more challenging. Conversely, the larger γ_x and γ_z the smaller the critical wave steepness $\frac{H_b}{L_{x,b}}$, making waves more prone to breaking.

c.   Results of Refraction-Diffraction Model

The equations derived from the shoaling-breaking equations can be transformed into refraction-diffraction equations using the method proposed by Hutahaean (2003). The refraction-diffraction model is executed with two ε values: 0.005 and 0.01, considering the bathymetry of a submerged island (Fig (1)). Contour plots of 2D wave height are presented in Fig (2), with (a) using $\varepsilon = 0.005$

and (b) using $\varepsilon = 0.01$. Three-dimensional contour plots are depicted in Fig (3).
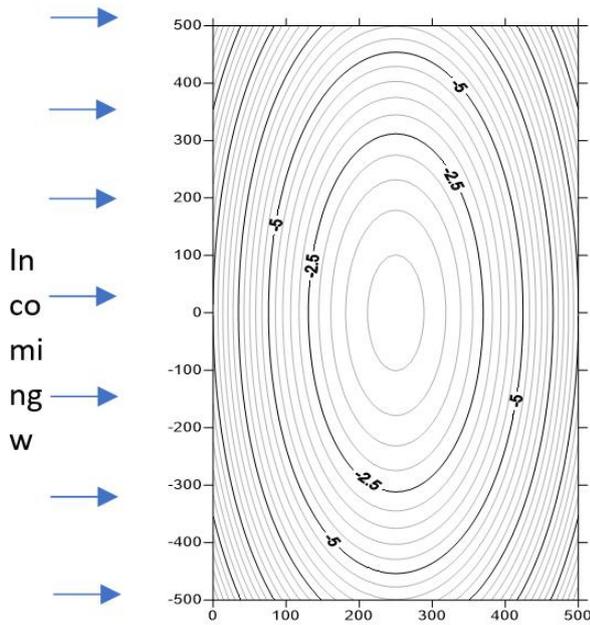
Fig.1: Contour of Submerged Island Bathymetry

(a)   (b)
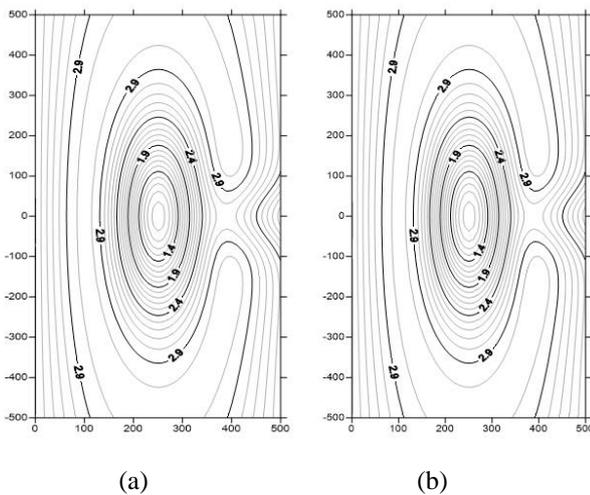
Fig.2: Contour of Wave Height
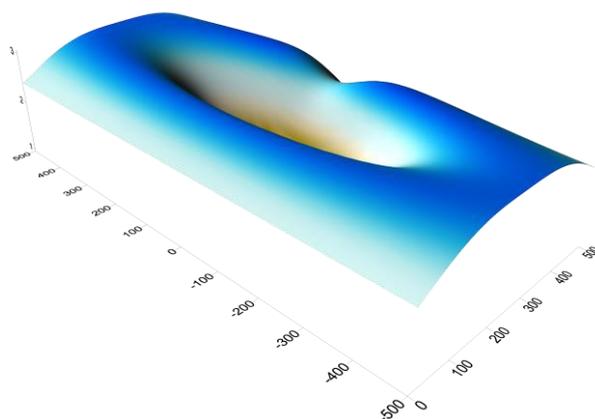
Fig.3: 3D Contour of Wave Height

Both refraction-diffraction model results show no discernible differences. From these findings, it can be concluded that the contribution coefficient does not play a significant role; the primary factors at play are the main values of weighting coefficients.

In conclusion, the results of the study on weighting coefficients are as follows:
The baseline values of weighting coefficients are,
For the function $f(x,t)$: $\gamma_{t,2} = 2.0, \gamma_x = 1.0$
For the function $f(x,z,t)$: $\gamma_{t,3} = 3.0, \gamma_x = 1.0, \gamma_z = 1.0$
The recommended corrected values for the weighting coefficients are based on the optimization coefficient $\varepsilon = 0.01$ where, $\gamma_{t,2} = 1.99960$, $\gamma_{t,3} = 3.00980$, $\gamma_x = 0.99758, \gamma_z = 1.02295$.

VII.   CONCLUSION

As widely recognized, the precision of the Taylor series hinges on the inclusion of high-order terms. The greater the number of these terms, the more accurate the approximation becomes. High-order terms encapsulate essential features of the function under consideration in the series, making them indispensable. When restricting a series to only first-order terms, the incorporation of a set of weighting coefficients becomes necessary to account for the high-order terms, resulting in a weighted Taylor series.

The Central Difference Method establishes the foundational values for these weighting coefficients. These baseline values undergo refinement through the inclusion of contribution coefficients derived from high-order terms with odd differentials, introducing relatively minor adjustments. In the context of modeling shoaling breaking, these contribution coefficients make subtle corrections to breaking characteristics, particularly at the third decimal place. Notably, the baseline values of weighting coefficients are derived without a prerequisite knowledge of the functional form, while determination of contribution coefficients relies on knowledge of the functional form. Thus, it is evident that baseline values hold a general applicability across various functional forms.

Despite the modest impact of contribution coefficients on both weighting coefficients and model outcomes, their significance should not be understated, as they play a crucial role in ensuring accuracy in balance equations. In models demanding high numerical precision, such as time series models, it is advisable to utilize weighting coefficients corrected by contribution coefficients to enhance accuracy.

REFERENCES

[1] Hutahaean, S. (2021). Weighted Taylor Series for Water Wave Modeling. International Journal of Advance Engineering Research and Science (IJAERS). Vol. 8, Issue 6;

Jun, 2021, pp 295-302. Article DOI: https://dx.doi..org/10.22161/ijaers.86.37.

[2] Hutahaean, S. (2022). Wavelength and wave Period Relationship with Wave Amplitude: A Velocity Potential Formulation. International Journal of Advance Engineering Research and Science (IJAERS). Vol. 9, Issue 8; Aug, 2022, pp 1-7. Article DOI: https://dx.doi..org/10.22161/ijaers.98.38.

[3] Arden, Bruce W. and Astill Kenneth N. (1970). Numerical Algorithms : Origins and Applcations. Philippines copyright (1970) by Addison-Wesley Publishing Company, Inc.

[4] Dean, R.G., Dalrymple, R.A. (1991). Water wave mechanics for engineers and scientists. Advance Series on Ocean Engineering.2. Singapore: World Scientific. ISBN 978-981-02-0420-4. OCLC 22907242.

[5] Hutahaean, S. (2023a). Water Wave Velocity Potential on Sloping Bottom in Water Wave Transformation Modeling . International Journal of Advance Engineering Research and Science (IJAERS). Vol. 10, Issue 10; Oct, 2023, pp 149-157. Article DOI: https://dx.doi..org/10.22161/ijaers.1010.15.

[6] Hutahaean, S. (2023b). Breaker Indices in Water Wave Formulated from Kinematic free Surface Boundary Condition, Conservation Equation of Wave Number and Equation of Energy Conservation. International Journal of Advance Engineering Research and Science (IJAERS). Vol. 10, Issue 1; Jan, 2023, pp 68-75. Article DOI: https://dx.doi..org/10.22161/ijaers.101.11.

[7] Michell, J.H. (1893). On the highest wave in water. Philosophical , (5), Vol. XXXVI, pp. 430-437.

[8] Toffoli, A., Babanin, A., Onaroto, M. and Wased, T. (2010). Maximum steepness of oceanic waves : Field and laboratory experiments.Geophysical Research Letters. First published 09 March 2010.https://doi.org/10.1029/2009GL.0441771

[9] Wiegel,R.L. (1949). An Analysisis of Data from Wave Recorders on the Pacific Coast of the United States, Trans.Am. Geophys. Union, Vol.30, pp.700-704.

[10] Wiegel,R.L. (1964). Oceanographical Engineering, Prentice-Hall, Englewoods Cliffs, N.J.

[11] Komar, P.D. & Gaughan M.K. (1972). Airy Wave Theory and Breaker Height Prediction, Coastal Engineering Proceedings, 1 (13).

[12] Mc Cowan, J. (1894). On the highest waves of a permanent type, Philosophical Magazine, Edinburgh 38, 5th Series, pp. 351-358.

The Feast of the Divine Holy Spirit and the Sacralization of Spatiality in Manicoré-AM / Brazil

Geanne Ferreira Leite, Tainá Trindade Pinheiro, Rayla de Lima Tavares, Maria das Graças Silva Nascimento Silva, Josué da Costa Silva

Universidad Federal de Rondônia, UNIR, Brazil

Abstract— The purpose of this article is to study the spatiality of the Divine Holy Spirit Festival in Manicoré/Amazonas through the symbologies of the festival and the devotees' spatial relationships with the place. In this way, the aim is to understand the affective relationships, the diversity of perceptions gauged and present significant points, addressing the relationship of the subjects in their living space. From a phenomenological perspective based on Relph (1978), the study was carried out through fieldwork and interviews, which formed part of the research methodology. Thus, the Divine Holy Spirit Festival can be understood as more than just a festival, but as resistance to the popular tradition that holds it, a sense of the sacred and of life itself.

I. INTRODUCTION

The Amazon is constantly represented by an imaginary of dense forest and historically exploited by the stereotype of "exotic", but its characterization cannot be restricted to this imaginary, leaving aside ethnic, linguistic, religious and cultural diversity.

From this perspective, human geography, in characterizing place as an experience, is similar to what phenomenologists attribute to the concept of the world, which would be the set of subjective experiences of the subjects, the essence, that is, "that which first appears to consciousness" (Neto, 2009, p.112).

In this context, the aim of this text is to study the spatiality of the Divine Holy Spirit festival in the municipality of Manicoré, in the state of Amazonas, in the northern region of Brazil, the Amazon *(Fig. 1)*. It seeks to interpret the symbolic meanings of the festival and its importance for the devotees and the relationships of the subjects in their living space.

When the Folia do Divino Espírito Santo takes place, as a cultural manifestation, the resistance of the popular tradition that holds it, the sense of the sacred and of life itself are also present.

Fig. 1: Location of the Community of Divino Espírito Santo Municipality of Manicoré/AM

Source: Google Maps satellite image, 2023.

II. METHODOLOGY

The work was based on a qualitative, bibliographical approach and field research. The method used was Relph's (1978) phenomenological method. This method allowed

the research to transcend objective analysis, making it possible for the research subjects to participate with their perceptions and experiences. This method has currently been used in geographical science as a way of understanding social, cultural and other phenomena whose analysis is subjective and phenomenologically based.

In this research, the method allowed us to participate in the moments relating to the festival of the divine, with a phenomenological look at space and symbolism, listening to people and their narratives as part of the research, considering the lived world.

The methodology was based on fieldwork that took place in July 2022 and July 2023, when the festival took place, where it was possible to apply the techniques of conversation circles, interviews, questionnaires, recordings and photographs.

The fieldwork took place by river, using a recreational boat that runs weekly between the municipalities of Porto Velho, Rondônia, and Manicoré, Amazonas. It was a quiet trip, lasting two days, and it was possible to appreciate the diversity of the Madeira River landscape, as well as the riverside communities that live on its banks.

III.   THEORETICAL REFERENCE

The celebration of the Divine Holy Spirit takes place in different places and each location presents new realities, symbologies and rituals. Each festival has its own identity and specificities spread over time and space, but they all have a common basis: popular resistance in the face of a contradictory and unequal reality.

The tributes to the Divine Holy Spirit, in a general context, were introduced to Brazil during the process of Portuguese colonization, establishing popular ties, with a strong influence from the Catholic religion and its festivities. Along with Portuguese colonization came contributions from other ethnic groups such as the first indigenous inhabitants and Africans.

In some places, more recently, and in others with greater antiquity and not necessarily in a continuous way, the Feast of the Holy Spirit remains a tradition, not only in Portugal (Tomar, Soure, Azores, Madeira, for example) but also in other territories of Portuguese domination and colonization, which is the case in Brazil, in addition to those localities that went through the Azorean immigration process (Mariano, 2020, p 58).

In the Brazilian tradition, the Divine Holy Spirit festivities take place in an annual cycle, which escapes the logic of modern reproduction, and strengthens the bonds of affection, emotion and faith, not only among the organizing revelers, but the expansion of the sacred that involves everyone who participates and interacts. In this context, we understand sacred space based on Rosendahl:

> *Sacred space as a field of forces and values that elevates the religious man above himself, that transports him to a different environment from the one in which his existence takes place. [...] it is the result of a manifestation of the sacred, revealed by a spatially defined hierophany (2002, p.81).*

Within this context, the space of the sacred is understood as the representation and symbolic appropriation of a defined territory, its materiality being a network of human relationships much more associated with the faith employed in the symbols and rituals of the festival than with the materialism used to bring the festival to life.

Relph (2014) explains that the concept of place emerged as a concern for study in geography in a period called the "spatial turn", due to the epistemological changes that occurred in geography because of its past dedicated to describing and mapping the diversity of places on Earth, due to colonization from the Greeks and Romans to the Europeans. Place in geography, especially in the 1970s and 1980s, became an alternative to the flattening of the discipline, justified by the authority of philosophers of science. Relph considers that place is the phenomenon of experience, which would make understanding this experience more assertive if it were explained by the approach developed by Husserl and Heidegger, which underpinned the work of Yi-Fu Tuan, David Seamon, Anner Buttimer, Relph himself and others. So this perspective came to be called humanist geography (Relph, 2014).

By the 1990s, interest in the study of place was restricted to humanistic geography and some strands of environmental psychology and architecture, and according to Relph, it was a small field of study. However, the study of place emerged in an "intellectual movement that sought to move away from the universalist propositions of modern thought and design towards postmodernism and the celebration of difference, whether racial, sexual, political or architectural" (Relph, 2014, p. 20). And in this context, the study of place has become an interest of various disciplines.

Geography as a study of place refers to particular observations in order to understand the ways in which human beings relate to the world. For Relph, this is presented as aspects of place and among the aspects listed by Relph we highlight spirit of place, which refers to "an idea that derives from the belief that certain places were occupied by gods or spirits whose supernatural qualities were evident in the setting" (Relph, 2014, p.23).

Nowadays, the term "spirit of place" refers to places that have a very strong identity. Relph believes that all places have their own physiognomy, but the spirit of place is characteristic of exceptional places.

Based on these fundamental concepts, we reflect on how the religious celebration of the Divine Holy Spirit is apprehended in the context and experiences of Amazonian riverside communities, with the meanings and attitudes that ordinary people build about the space and environment in which they live and the relationship that permeates the sacralization of the space lived during the days of celebration.

IV. RESULTS AND DISCUSSION

The Brazilian Amazon has a cultural wealth that has been suppressed by historically constituted disputes. Furthermore, this region is constantly associated with its fauna and flora, and is recognized as one of the most outstanding regions in terms of biodiversity. However, these narratives presuppose the region as an infinite and available source of natural wealth to meet economic needs in a geopolitical context of the international market, making the existence and experiences of local populations unfeasible. Following this perspective, Tuan:

> *A large region, such as the nation-state, is beyond the direct experience of most people, but it can be transformed into a place - a location of passionate loyalty - through the symbolic medium of art, education and politics" (Tuan, 1995, p. 149).*

The Festejo do Divino Espírito Santo, in the municipality of Manicoré, Amazonas, presented in this text, has its spatiality in the countryside and in the city. Through field research and bibliographical research, aspects of place and sacredness are highlighted, as well as the relationship of belonging and collectivity in the riverside communities of Manicoré, especially Barreira and Igarapezinho.

Barreira de Manicoré/AM, started the festival far from the current region, in Alto Madeira, Lake Acará in the 1940s, through Mr. Antônio Procópio and Mrs. Luiza, residents of the place, who made a promise to benefit the health of their son, a six-year-old boy at the time, who was shot in the leg.

As it was a community far from the municipality's headquarters and with few economic resources at the time, the parents committed themselves to holding prayers and get-togethers in honor of the Divine Holy Spirit if the child was cured, and so they did. When the boy turned 15, the couple brought him to be baptized in the city of Manicoré, and when they got to know the place called Barreira de

Manicoré, they felt welcomed and decided to live in the community. With them also came the tradition of devotion to the Divine Holy Spirit for the community.

> *"The Divine is the Third Person of the Holy Trinity. He is God himself, king of the universe. There are several people who accompany the festival and form the committee: we have the Mantenedor, the Cacheiros, the Judges and the Foliões. We have those responsible for the litany (prayer sung in Latin), the box of the Divine (zabumba), the Andor, the Mast and the flags, a tradition that has continued since the time when the Divine traveled in procession in small Igarités (canoes) in the communities".*

An account given in a conversation with Deacon José da Silva Carneiro, a resident of the city of Manicoré and a regular devotee of the Divine festival in the community.

After the accident, the family, who had recently arrived in the community, began to hold two (02) days of festivities every year in their own home, in honor of the Divine Holy Spirit, with the praying of the litany (in Latin) and a grand banquet, where all the families who lived there were invited to take part. At one of the festivals, the town's priest was invited to take part and suggested that the residents build a chapel so that the community could come together to pray. Gardin expresses this relationship of sacralization of space as:

> *The land, in turn, was given a sacred meaning, in other words, it was blessed and recognized first and foremost by the Church, in a presence that was felt in every nook and cranny. As the sacralization of the land preceded the other acts of administration, the names given to places of agglomeration were always preceded by the name of the saint who protected each place (1999, p. 120).*

Fig. 02 and 03: Chapel of the Divine in the community of Barreira de Manicoré

Source: Manicoré Barrier Community Secretariat, 2022

Describing the feelings involved in a community's devotion to the Divine, using phenomenology, helps us to understand how the faithful construct and (re)construct symbolic spaces. The history of the festival in both the Barreira community and the Igarapezinho community was made possible through documents and interviews with members and devotees, in which participation was fundamental. The importance of recording part of this history in detail is highlighted in the words of one interviewee:

> *"The Divine Holy Spirit of the city is the main Divine Holy Spirit, the Holy Trinity. The Divine Holy Spirit of Barreira, on the other hand, is the Divine Holy Spirit of the innocent. We need to recover the history... it's a tradition that if you don't build up these documents will be lost, the old people will die and so will we, and then our generation, what will they answer?"*

In the Old Testament of the Catholic Bible, the figure of the dove appears as a symbol of God's peace and forgiveness, when Noah releases the dove into the sky and returns to the ark carrying an olive branch. In the New Testament of the Catholic Bible, the Holy Spirit appears in the form of a dove at the Baptism of Jesus. The halo of three rays on his head signifies that the Holy Spirit is part of the Holy Trinity. And in the passage of Jesus' baptism quoted by John the Baptist, we have the Father, the Son and the Holy Spirit revealing themselves as Trinity to humanity.

Fig 04: Scaffold with the image of the Dove for the festive procession.

Source: Field research collection in 2023

Regarding the post-coronavirus pandemic festivities (COVID-19), teachers Angelita Ferreira and Angelica Ferreira, daughters of one of the founding couples of the Barreira community, Mr. Pedro Ferreira and Mrs.

Raimunda Cabral, told us in an interview about the satisfaction and commitment of the whole family in participating in the festivities since they were organized, even though they no longer live in the community.

> *"Devotion to the Divine has been passed down to us since childhood, it's the heritage our parents left us and it's a joy to be able to take part in every detail of the festival with the whole family."*

Still on the subject of this year's festival, Mrs. Antônia do Socorro Ferreira told us how thrilled she was to return to the community for the four (04) days of the festival, having been suspended for two years due to Covid-19.

> *"On the last day of the festival, the coordinators organized a procession to the home of Jaime Cunha, a former resident who recently lost his sight and was unable to attend the festival, a tradition he had always kept over the years. At that moment, everyone was moved by the prayers and his words of thanks".*

According to Claval (1999, p. 115) "Sharing the same religious or metaphysical beliefs and taking part in the same rites that bring believers together constitute very solid social foundations".

The festival involves the entire local population and nearby communities, with rites performed in the churches, as well as itinerant events, where the devotees' homes are visited. The itinerants are welcomed into the homes, in a relationship of welcome and belonging with great spiritual and cultural significance. The families who are visited make all the preparations, such as the logistics of sleeping, guarding the ark of the divine, food for the members of the organization and visitors, and the celebratory service. The family sees itself as having received a visit from the divine.

Fig 05: Committee decorating the altar for the celebration of Holy Mass

Source: Manicoré Barrier Community Secretariat, 2022

The days of the festivities begin with the procession at around 6:00 p.m. At this time, it is possible to see a large movement of people, pick-up trucks with people in the back of the vehicle, which is a common practice during the festivities. The procession ends at the church, where it begins with praises, a festive Mass and then the auction of gifts and food to raise funds.

Fig.6: Gifts (roast chickens) for the Auction

Source: Manicoré Barrier Community Secretariat, 2023

In the procession it is possible to arrive and take part, the welcome is widespread, and this moment also represents reunions between distant family members and friends, in which emotional ties and a sense of community are strengthened, everyone knows and recognizes each other.

It is important to emphasize that the relationships involving the populations of this region are left out of the analysis, mainly because natural resources play a leading role and there is an obligation, even if utopian, to save the planet. Another question could be raised about "non-places", which could be those where there is no understanding of their meanings for various reasons such as ruptures, construction and the "excesses" of super modernity or globalization. Even with the "standardization" imposed by postmodernity, there are characteristics of existence, of being-in-the-world that are independent of a superstructure, because, although they are influenced, they don't have the "power" to dissolve sensations (Tuan, 1980).

> *Human places vary greatly in size. An armchair by the fireplace is a place, but so is a nation-state. Small places can be known through direct experience, including the intimate sense of smell and touch. A large region, such as a nation-state, is beyond the direct experience of most people, but can be transformed into a place - a location of*

passionate loyalty - through the symbolic medium of art, education and politics (Tuan, 1995, p. 149).

In this way, Tuan does not refer to the static nature of space, but aims to highlight the materialization of experiences in their dynamics, something common in the subject's relationships. From this perspective, place is the "fixed" point of the common meeting of different experiences, in other words, "experience" as the foundation for the constitution of "identity" for that group. Experience means the ability to learn from one's own experience. And in this process, thought and feeling are involved as elements of their modification and insertion into the world (Tuan, 1983).

The festivities in honor of the Divine Holy Spirit in the Igarapezinho community began with the family of Mr. Eugênio Rodrigues Pinheiro and Mrs. Maria Rodrigues Pinheiro, who prayed the litany in their own home and who, from 1938 onwards, began the religious walk in honor of the Divine with the participation of the community.

After a few years, Mr. Agnaldo Ramos Ferreira was chosen as the community's president and began building a little wooden chapel covered in straw to be used for the community's festivities. However, in 1961, the chapel caught fire, so the community got together again to build a new chapel. In 1970, they began their evangelization journey, which consisted of visiting nearby communities.

Fig 07: Chapel of the Divine in the community of Igarapezinho – Manicoré

Source: Field research collection in 2023

After a few years, Mr. Agnaldo Ramos Ferreira was chosen as the community's president and began building a little wooden chapel covered in straw to be used for the community's festivities. However, in 1961, the chapel caught fire, so the community got together again to build a new chapel. In 1970, they began their evangelization journey, which consisted of visiting nearby communities.

In 2001, the Divine Holy Spirit commission was set up, responsible for visiting families in the municipality and the pilgrimage culminates in the celebration of the feast of

Pentecost and precedes the four nights of festivities of the Divine Feast in the community

Fig 08: Commission of the Divine Holy Spirit, responsible for visiting families in the town center

Source: Field research collection in 2023

In an interview, Celia Belolo, a community member from Igarapezinho, told us how they created the history of the community's Divine Feast and the tradition of sharing food on feast days, especially during the pilgrimage of the image of the Divine to visit homes.

> *"I went to Mr. Quintino's house, to other people's houses, Aunt Raimunda passed by and then we were able to gather the information and that history was made... because when people ask us.... right now at the* Manicoré quadrilha *festival* [Folkloric Festival of Quadrilhas in *Manicoré-AM*] *there are going to be two groups with the theme of the Divine, which is Manicorezinho and Santa Luzia... so it's a tradition that if you don't build up these documents we're going to lose."*

About the itinerary of visits of the image of the divine to the houses, she says:

> *"In Manicoré they visit all the neighborhoods... here people prepare from one year to the next, they kill pigs, because it's a lot of people so in the house where the revelers* [people who take part in the festival] *sleep there are a lot of people... and so it's that joy of people preparing that food.... once a priest came and said 'I think you're doing the wrong thing by giving the food, you're giving the money' and we said 'Father, we're happy to give the food'.... because we see them when they leave* (for the pilgrimage) *... during the morning they go about their business and in the afternoon they visit... and it's such a fervent tradition that out of 200 families here in the community only 1 doesn't take part".*

In this account we can see the confluence between the community and the sacredness of the space, presenting another aspect of the place, the sense of home and belonging "where the roots are deeper and stronger, where one knows and is known by others, where one belongs" (Relph, 2014, p. 24).

Still on the importance of the Divine festivities for the municipality of Manicoré, Kartegiane Moraes, presenter of the folkloric group Juventude da Roça, said in an interview with the Secretariat of Culture and Tourism - SEMCULT - that the theme of their Junina 2023 was, "all the devotees of the Divine Holy Spirit are being honored, the expectation strengthens us, to speak of the Divine in an authentic way for us will be to portray the community of Igarapezinho, and I'm sure that this will be the differential in the presentation".

Fig 09: Juventude da Roça folklore group with the theme "Divino - Devotion, Culture and Tradition".

Source: Municipal Department of Culture and Tourism - SEMCULT 2023

The Festa endures, in a symbolic space, with greater intensity in the days of the annual cycle, but it is also present in everyday life, whether in the waiting or in the preparations. This is a character that represents a break from everyday life to pay attention to the potential of one and all, under the essence of spirituality and, above all, faith.

V. CONCLUSION

In this text, it was possible, through the science of geography with a humanistic bias, to understand how cultural and religious manifestations present an aspect of

the sacredness of lived space. Thus, we reflected on the way in which the relationship between people, space and religion presents aspects that bring a greater understanding of the connection between people's spirituality and the changes caused in their geographical space (Costa, 2017).

The Festival is a get-together in which everyone plays an important role, so all the rules and systems of the Festival of the Divine are in tune with something inexplicable and superior, and which contradicts all the rational logic of the modern world. It is important to maintain the traditional manifestations and pass on the organizations to future generations. And so, through annual repetition, tradition is built into a new territoriality.

Therefore, based on fieldwork with the support of phenomenology, we understand that even though it is immersed in Catholicism, it expresses African and indigenous ancestry through various elements of the festival, constituting a unique spatiality, which makes the festival a link to the sacredness of space and the strengthening of interpersonal and community relations, in the dissemination of religiosity, culture, memory and the temporality of Amazonian populations.

REFERENCES

[1] A Claval, P. Cultural Geography. Translation: Luiz Fugazzola Pimenta; Margareth Afeche Pimenta. Florianópolis: Ed. da UFSC, 1999.

[2] Besse, Jean-Marc. Seeing the Earth: Six essays on landscape and geography. Editora Perspectiva S.A. São Paulo, 2006.

[3] Costa. Meridiana Soares. Geography and Religiosity: The Celebration of the Divine Holy Spirit in Guajará-Mirim-RO / Meridiana Soares da Costa. -- Porto Velho, RO, 2017

[4] Gardim, Cleonice. Campo Grande between the sacred and the profane. Campo Grande: UFMS, 1999 (Fontes Novas - Especial - 100 anos de Campo Grande).

[5] La Blache. V. de (1985). The characteristics of geography. In CHRISTOFOLETTI, Antonio -organizador (1985).Perspectivas da Geografia. São Paulo: DIFEL, p. 37-47.

[6] Mariano, N. F. (2020). The Feast of the Divine Holy Spirit: a tradition in motion. PatryTer -Latin American and Caribbean Journal of Geography and Humanities,3(5),58-71.

[7] Neto, Necio Turra . In search of a new place. In: VESTENA, L. R. Et al. (org.). Geographical knowledge: theories and applications. Guarapuava (PR): Unicentro, 2009, p. 112

[8] Relph, Edward. Reflections on the Emergence, Aspects and Essence of Place. IN: Marandola Jr. Eduardo; Holzer, Werther; Oliveira, Lívia de. What is the Space of Place? Geography, Epistemology, Phenomenology. São Paulo. /editorora Perspectiva. 2014.

[9] Relph, E. C. The phenomenological bases of geography. April, 1978.

[10] Rosendahl, Zeny et alii (Orgs.). Landscape, imaginary and space. Rio de Janeiro: EdUERG, 2001.

[11] Teixeira, M.; Castilho, M.A. A territorialidade e a sacralização do espaço e fronteira no Brasil (colônia/império). Multitemas, Campo Grande-MS, n. 33, p. 5, Apr. 2006.

[12] Tuan, Yi-Fu. Space and place: the perspective of experience. São Paulo: Difel, 1983.

[13] Tuan, Yi-Fu. Humanistic geography. In: Christofoletti, Antônio (Org.) Perspectives on Geography. São Paulo, Difel, 1995. p. 143-164.

OJS Editorial and Publishing Process

Author	Editor and Section Editor	Journal Manager, Reviewer, Copyeditor, Layout Editor, and Proofreader

Submission
Author uploads file to journal Web site, and enters metadata for OAI indexing

1. Submission Queue
Editor assigns submission to Section Editor to see through the editorial process

Journal Management
Setup and configure journal; enroll editors, reviewers, copyeditors, proofreaders.

Select Reviewers
Editor invites reviewers from database with interests, load

Submission Review
Author can track process, see files, reviews, revise and resubmit, at editor's request

2. Submission Review
a) Check submission
b) Conduct peer review
c) Reach editorial decision

Review Conducted
Reviewer submits review and recommendation (which may be rated by editor)

Submission Editing
Authors reviews copyedits and proofreads galleys

3. Submission Editing
a) Copyedit submission
b) Layout of formatted galleys
c) Proofread galleys

Copyediting

Layout
Layout Editor prepares galleys in HTML.PDF. PS. etc.

Proofreading

Key

Journal Manager	
Editor	
Section Editor	
Reviewer	
Copyeditor Layout Editor Proofreader	
Author	
Reader	

Open Journal Systems is an open source development of the Public Knowledge Project.

http://pkp.sfu.ca

4. Issue Management
a) Create issues
b) Schedule submissions
c) Organize Table of Contents

5. Publication
Offering immediate open access or delayed open access, with subscriptions

Submission Archive
Complete records kept of submission process for published and declined items

Current Issue
Items appear with Reading Tools linking to related internal and external resources

Journal Archive
Browsing issues, with indexing by OAI search engines, as well as Google, etc.

~IJAERS Workflow~

Important links:

Paper Submission Link:

https://ijaers.com/submit-paper/

Editorial Team:

https://ijaers.com/editorial-board/

Peer Review Process:

https://ijaers.com/peer-review-process/

Publication Ethics:

https://ijaers.com/publication-ethics-and-publication-malpractice-statement/

Author Guidelines:

https://ijaers.com/instruction-to-author/

Reviewer Guidelines:

https://ijaers.com/review-guidelines/

Journal Indexed and Abstracted in:

- Qualis-CAPES (A2)-Brazil
- Normatiza (Under Review-Ref.020191511)
- NAAS Score: 3.18
- Bielefeld Academic Search Engine(BASE)
- Aalborg University Library (Denmark)
- WorldCat: The World's Largest Library Catalog
- Semantic Scholar
- J-Gate
- Open J-Gate
- CORE-The world's largest collection of open access research papers
- JURN
- Microsoft Academic Search
- Google Scholar
- Kopernio - powered by Web of Science
- Pol-Index
- PBN(Polish Scholarly Bibliography) Nauka Polaska
- Scilit, MDPI AG (Basel, Switzerland)
- Tyndale University College & Seminary
- Indiana Library WorldCat
- CrossRef DOI-10.22161/ijaers

- Neliti - Indonesia's Research Repository
- Journal TOC
- WIKI-CFP
- Scinapse- Academic Search Engine
- Mendeley-Reference Management Software & Researcher Network
- Dimensions.ai: Re-imagining discovery and access to research
- Index Copernicus Value(ICV): 81.49
- Citeseerx
- Massachusetts Institute of Technology (USA)
- Simpson University (USA)
- University of Louisville (USA)
- Biola University (USA)
- IE Library (Spain)
- Mount Saint Vincent University Library (Halifax, Nova Scotia Canada)
- University Of Arizona (USA)
- INDIANA UNIVERSITY-PURDUE UNIVERSITY INDIANAPOLIS (USA)
- Roderic Bowen Library and Archives (United Kingdom)

- University Library of Skövde (Sweden)
- Indiana University East (campuslibrary (USA))
- Tilburg University (The Netherlands)
- Williams College (USA)
- University of Connecticut (USA)
- Brandeis University (USA)
- Tufts University (USA)
- Boston University (USA)
- McGill University (Canada)
- Northeastern University (USA)
- BibSonomy-The blue social bookmark and publication sharing system
- Slide Share
- Academia
- Archive
- Scribd
- ISRJIF
- Cite Factor
- SJIF-InnoSpace
- ISSUU
- Research Bib
- infobaseindex
- I2OR
- DRJI journal-repository

AI Publication

International Journal of Advanced Engineering Research and Science (IJAERS)

104/108, Sector-10, Pratap Nagar, Jaipur, India